SCIENCE TEACHER'S WORLD

Teacher's edition of Science World • February 10, 1959

The art of questioning

The art of questioning is related to teaching as the art of bowing is related to violin playing or as the art of casting is related to trout fishing. It is essential and fundamental. Properly worded questions put to the class at the psychological moment may stimulate curiosity, arouse interest, spur and guide thinking, encourage expression. Through sagacious questioning, the teacher can maintain attention, discover and diagnose weaknesses, and fix knowledge in the mind. On the other hand, poorly worded questions put to the class at the wrong time may make for discontinuous thinking and confusion. They may even lead the class entirely away from the topic under discussion. The present article is addressed to the teacher who wishes to improve himself in the art of questioning. As with any other art, improvement calls for meticulous attention to detail and constant practice.

What is a good question? A good question is direct and clear. It is simply worded in language the students can understand. It is rendered slowly — except when used in drill for rapid recall — and almost never repeated. In the main, the question appeals to the entire class. It calls for thinking and deliberation and for an answer in a complete sentence. In complex situations where a *series* of questions are asked, these are graded in difficulty. A teacher who asks good questions appears to be thinking with his students.

Some examples of good questioning. The teacher shows the class two 100-ml. graduates containing water up to the 100-cc. mark.

TEACHER: Let us call this cylinder (*points to one*) cylinder A, and this cylinder (*points to the other*) cylinder B. How much water does each cylinder contain? (*The teacher takes the cylinders around for the students to see.*) Here (*points to a third cylinder, this one of 500-ml. capacity*) is a larger graduate. If we pour the water from cylinder A and the water from cylinder B into the large graduate, what will the *total* volume of the liquid be? (*After the answer is given, a student is called upon to do the pouring. The teacher takes around the larger graduate so students can see that the water is at the 200-cc. mark.*)

TEACHER (*continuing*): Here is another cylinder A containing water and another cylinder B, this one containing not water but alcohol. (*Each cylinder is filled to the 100-cc. mark.*) How much liquid is there in each cylinder? (*The teacher takes around the cylinders so the students can see.*) If we pour the liquid from cylinder A and the liquid from cylinder B into the larger cylinder, what will be the total volume of the liquid? (*After the answer is given, a student is called upon to do the pouring. Then the teacher takes around the large cylinder for the students to examine.*) How do you account for the fact that the volume is *less* than 200 cc.?

Note that the teacher has set the stage for learning. He has led the class to a conflict of experience — a prime stimulus to thinking. But in most science-teaching situations, the conflict of experience may not be so obvious. The teacher may have to resort to a more complex *series* of questions to bring it about. For example, let's listen in on a teacher whose class has just read, or been told, that secretion of pancreatic juice is accelerated a minute or so after food enters the duodenum from the stomach. Appropriate charts and models are on display. (Note: The student responses given below are "target" answers. A student, naturally, answers in his own words, and a teacher might have to do some prodding to elicit an answer that is precise.)

TEACHER: Let's see if we can get to understand this better by going back to something we have studied before, namely, the secretion of *saliva*. Exactly where are the salivary glands?

STUDENT: Two are in front of the ears, two under the jaw, and two under the tongue.

TEACHER: When food is in the mouth, with what cells is the food in contact?

STUDENT: The food is in contact with cells of the lining of the mouth.

TEACHER: How do we explain the fact that when food enters the mouth the flow of saliva is accelerated?

STUDENT: Messages are sent through nerves to the salivary glands.

TEACHER: What experimental evidence is there to support our explanation?

STUDENT: If the nerves are cut, the salivary glands do not respond.

TEACHER: Now let us turn our attention to the secretion of pancreatic juice in the intestine. Where is the pancreas in relation to the intestine?

STUDENT: The pancreas is outside the intestine.

TEACHER: With what cells is the

STW Contributing Editors: Alexander Joseph, Zachariah Subarsky

food in contact when the food is in the duodenum?

STUDENT: The food is in contact with the cells of the lining of the duodenum.

TEACHER: How may we explain the fact that when food enters the duodenum the flow of pancreatic juice is accelerated?

STUDENT: Messages are sent from the lining of the duodenum to the pancreas.

TEACHER: What would be the effect of cutting the nerve between the duodenum and the pancreas?

STUDENT: The pancreas would not respond.

TEACHER: How many in the class agree? (*Generally, all will agree.*) You are wrong! A minute or two after food enters the duodenum, the pancreas *does* respond. (*The class is now in a conflict of experience and is ready to study the story of the discovery of the hormone, secretin.*)

Note the gradation in difficulty of the questions in the above series: Where is . . . ? With what cells . . . ? How may we explain . . . ? What would be the effect of . . . ?

Let us now see how the teacher uses questions to advance a theory that explains the perplexing phenomenon.

TEACHER: In what part of the body does a doctor usually inject penicillin?

STUDENT: In the buttock.

TEACHER: Suppose a patient had an infected lung. In what part of the body would the doctor inject the penicillin?

STUDENT: In the buttock.

TEACHER: Why is it not necessary to inject penicillin directly into the lung?

STUDENT: The penicillin seeps into the blood, and the circulating blood carries it to all parts of the body.

TEACHER: What other parts of the body, in addition to the lung, would be reached by the penicillin?

STUDENT: The penicillin would reach all parts of the body.

TEACHER: Now, suppose the cells in the lining of the duodenum secreted a substance into the blood just as an injection does. What parts of the body would the secretion reach?

STUDENT: The substance would reach all parts of the body.

TEACHER: When the secretion reached the pancreas, what might the pancreas be stimulated to do?

STUDENT: The pancreas might be stimulated to release pancreatic juice into the intestine.

TEACHER: How may we explain the fact that a minute or two after food enters the duodenum, the flow of pancreatic juice is accelerated?

STUDENT: When food comes into the duodenum, the cells in the lining of the duodenum secrete a substance into the circulating blood. When this substance reaches the pancreas, the pancreas releases its juice into the intestine.

The teacher might then ask students to suggest a possible experiment to test the truth of this theory.

The poor question. Many of the so-called poor questions listed below are used occasionally by the best teachers. In fact, under certain conditions and for certain special purposes, these kinds of questions may prove to be the most effective. It is true, nevertheless, that such questions do not tend to stimulate good thinking. Nor do they give the student practice in thought expression. The work of beginning teachers, of below-average teachers, of nervous teachers, and of teachers with poor discipline seems to be characterized by extensive use of questions like these:

The question that *answers itself*: "Don't substances expand when they are heated?" "Isn't sodium hydroxide a base?"

The *leading* question: "Is the pole of a magnet the place where most of the magnetic strength is concentrated?" "Is chlorine a halogen?"

The *tugging* question: "Density is mass divided by what?"

The *ambiguous* question: "What happens when there is a short circuit?" "What takes place when an acid touches a metal?"

The *double* question: "Who discovered what about the action of electric currents in solutions?"

The *indefinite* question: "What about the specific heat of water?"

The *guessing* question: "Is sodium bicarbonate an acid or a base?"

The *echo* question: "Acceleration is velocity divided by time. What is acceleration?"

The *elliptic* question: "The atomic weight of oxygen is . . ." "The mechanical advantage of an inclined plane is the length of the incline divided by its . . ."

Faults in questioning. The lessons of some teachers include questions that are too easy or too difficult, too many or too few. A catechismal lesson can be as monotonous as a dull lecture. Questions that are too easy lead to inattention, and questions that are too difficult fail to stimulate student activity. If a teacher has to repeat questions constantly, there is something wrong with the way they are asked or with the questions themselves. A question that is foreign to a student's experience is a perfect waste of time.

A teacher who concentrates a series of questions on a single student soon loses the attention of his class. This is especially true when a student is at a chart in the front of the room and is engaged in a dialogue with the teacher.

The teacher who directs his questions to individuals by first calling the name of a student and then stating the question does not get as much class attention as the teacher who states his question to the class and *then* asks a specific student to answer it.

Good professional practice. If you would improve yourself in the art of questioning, make it a practice to incorporate critical and strategic questions in your lesson plan. Write them down, together with the "target" answers. Scrutinize them in the light of this discussion, improve them (if necessary), and then use them. There is nothing wrong with a teacher's pausing in the course of a lesson to look in his lesson plan. Look down into your plan book, read the question to yourself, then look up and put the question to the class with confidence. Above all, be enthusiastically interested in the answer. As you improve in the questioning art, you will find that your teaching improves. —ZACHARIAH SUBARSKY

MEMO

To: Science teachers

Subject: Ways to use this issue of SCIENCE WORLD in the classroom

The X-15: Mach 7 manned rocket

PHYSICS TOPICS: action and reaction, acceleration
GENERAL SCIENCE TOPICS: jet engines, rockets

This up-to-the-minute account reads like the logbook of the future flight of the X-15. The reader is taken through each step of the flight from take-off to final landing. Each of the scientific aspects of the problem of manned rocket-plane flight is carefully developed in the article. The methodical and thorough steps taken during each phase of the flight, and the preparation and checkwork, indicate the difficult nature of the problem. This is an excellent article to use in connection with classwork on action and reaction.

Class discussion

1. Why is all of the X-15's fuel used in three minutes?
2. How is the X-15 controlled when it is in air too thin for the normal flight-control system to be effective?
3. How is the plane landed?
4. What are some of the safety devices for the pilot?
5. How is the cockpit cooled to remove the heat caused by air friction?
6. What are the four basic goals of the X-15 flight?

Class activities

1. Make a model of the X-15.
2. Demonstrate the operation of a simple model rocket plane operated by a carbon-dioxide cartridge or of a miniature toy Jetex dry-fuel engine.

The fickle measurement: weight

PHYSICS TOPICS: gravity, mass
GENERAL SCIENCE TOPICS: weight, gravity

This article, the first of two articles on weight, mass, and gravity, is designed to give the reader an understanding of the immutable nature of mass in contrast to the changing weight of the same mass at different latitudes and altitudes.

YOUNG SCIENTISTS

Teachers are urged to have their students submit write-ups of interesting projects or experiments they have done. If printed in SCIENCE WORLD, full credit will be given to the student, the school, and the teacher. In addition, the student will receive $15. Contributions should be addressed to Science Project Editor, Science World, 575 Madison Avenue, New York 22, N.Y. Students should be reminded that by submitting their ideas they can do a service to thousands of other students.

Mass and weight are confused more than any two other basic ideas in physics. Weight is merely the amount of gravitational pull on the atoms that make up the body or object. Since the number of atoms is not changed, the mass of these atoms remains unchanged. However, the pull of gravity can and does differ. To change weight in pounds into mass, simply divide by gravity acceleration — or 32 feet per second per second. Thus, a 160-pound weight has a mass of five slugs in the English, or Engineering, system.

Class activities

1. Select some well-known mountains whose altitude is known, and approximate a student's weight on top of each. Calculate what the student's weight would be on Mars and on the moon.
2. Have each student calculate his mass in slugs from his weight in pounds.
3. Make a simple two-arm balance from yardsticks, and use a standard weight to measure the weight of an unknown mass.

When the animal world sleeps

BIOLOGY TOPICS: hibernation, metabolism
GENERAL SCIENCE TOPICS: animal life, the seasons

This beautifully written article is a masterpiece of its type. It is not only good biology, but also first-

rate literature. In biology classes, the teacher can tie up the abnormally low metabolic rate of animals in hibernation with classwork in metabolism. In general science classes, the students can follow the ways animals adapt to seasonal changes. This is the type of article that deserves a permanent place in students' notebooks or study materials.

Class discussion

1. Why do animals hibernate?
2. How do animals that do not hibernate make adaptations to meet winter conditions?
3. What happens to the metabolism of a hibernating animal?
4. How do humans maintain life activity in cold weather?
5. How do cold-blooded animals adapt to winter conditions?

Class activities

1. Make pictorial charts to indicate how the various groups of animals meet winter conditions.
2. Take the temperature, by mouth, of frogs in water ranging in temperature from 80° F. to 40° F. Do this by dropping the temperature of the water in ten-degree steps.

Birth of the planets

PHYSICS TOPICS: gravitational attraction, centrifugal force
EARTH SCIENCE TOPICS: theories for the formation of planets
GENERAL SCIENCE TOPIC: planets

This article helps to round out the ideas on the origin of planets presented in high school and junior high school textbooks. It presents each of the important hypotheses in historical sequence and indicates the latest theories on the subject. The article is "must" reading for any class that is studying the planets or the solar system. It should be made a permanent addition to their notebook or study materials.

Class discussion

1. What are the different hypotheses that have been proposed for the origin of the planets?
2. Explain each of the hypotheses.
3. Why were many of the hypotheses dropped?
4. What are the latest theories concerning the origin of planets?

Class activities

1. Have students make a model of the solar system, using balls of different sizes as planets.
2. Have students paint large cardboard disks to resemble spiral nebulae.
3. Have students make charts to illustrate the different theories concerning the origin of planets.

Neither soft nor brittle

CHEMISTRY TOPICS: organic chemistry, synthetics, polymers
GENERAL SCIENCE TOPIC: plastics

This interesting and timely article deals with a new plastic, Delrin. It not only describes the nature of this particular substance, but also presents a thorough explanation of the nature of plastics and the principal types of plastics. It explains what polymers and monomers are. And it indicates areas where plastics can replace metals. This is one way in which we may be able to overcome an eventual shortage of metal resources.

Class discussion

1. What are the basic units of common plastics?
2. What is polymerization?
3. Into what two general categories are plastics divided?
4. What is the molecular weight of Delrin?
5. What two facts point to an increasing use of plastics in the years ahead?

Class activities

1. Make a display of simple materials made from different plastics.
2. From a scientific supply house obtain a kit used for the embedding of specimens in plastic. Use the kit to cast clear plastic shapes.

Regeneration in Planaria

BIOLOGY TOPIC: regeneration
GENERAL SCIENCE TOPIC: growth

This fascinating article by a biology student is one that may inspire many other students to carry on the same type of work. It should also stimulate students to try other types of simple biological research and to send to SCIENCE WORLD articles concerning research they may have already done. The possibility of publication can serve as an excellent motivation for laboratory work.

Class discussion

1. What was the purpose of this student's research?
2. Why can it be said that binary fission is involved?
3. What parts of the *Planaria* will regenerate?

Class activities

1. Carry out some of the experiments described in the article. If *Planaria* are not found locally, they may be purchased from a biological supply house. (Be sure to specify *live* planarians.)
2. Try regeneration experiments with legs of salamanders.

SCIENCE WORLD

ARY 16, 1959

X-15: BEGINNING OF THE SPACE AGE

(see page 22)

THE SCIENCE MAGAZINE FOR HIGH SCHOOL STUDENTS

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Features

Stranger Than Fiction

Departments

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Have you renewed your subscription?

This is the first issue of the second semester. If your *SW* subscription was for the school year, SCIENCE WORLD will continue to reach you automatically. But if you were a one-semester subscriber, you must renew now in order to go on receiving *SW*.

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A reminder: The start of a new semester is a fine time for good resolutions. Make yours a resolution to drive safely this term — and thereafter.

Coming in SW, February 24

If you are "weightless" in an earth satellite, can you crack a walnut with a hammer?

Why will satellite construction men have to be trained to think in terms of mass, not weight?

What new frontiers are opening up in the field of vaccines?

How does a radio telescope work? What information does it give us?

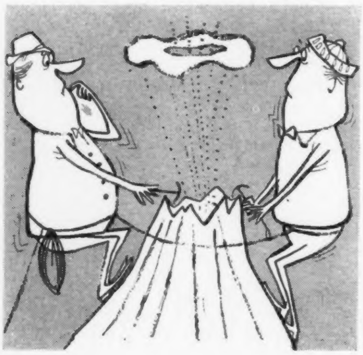
Can an amateur build a computer?

For answers, see next issue of *SW*.

Richard Harvey of Providence, Rhode Island, writes:

What causes volcanoes to erupt?

There is no single cause of volcanic eruption. In general, a volcano erupts when heated material deep in the earth escapes under pressure through channels of weakness in the earth's crust. The greater the depth, the hotter the earth becomes. Hot molten rock (or magma) far below the earth's surface contains gases that are under tremendous pressure. If a passage, or vent, in the earth's crust is opened, the pressure forces gases and magma upward to the earth's surface. (Apparently, such passages were originally opened up when movements of the earth's crust caused it to fracture. In some cases, gas pressure may have been great enough to open its own passage.) Magma that reaches the earth's surface is called lava. When the gas ceases to rush up, the lava cools, solidifies, and plugs the passage. Another eruption will occur when enough pressure is built up to break the plug.



Andrew Eells of Stone Harbor, New Jersey, writes:

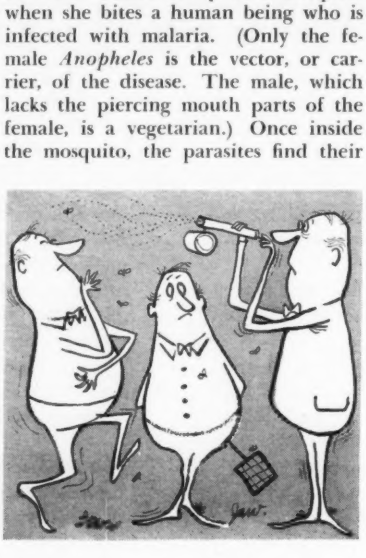
How are solid-propellant rockets launched?

In solid-propellant rockets, as the name implies, fuel and oxidizer are mixed together in a solid charge. The charge is stored right in the combustion chamber, where it is burned. Solid-fuel rockets burn rapidly and release great volumes of gas. That's why they are used when a lot of thrust is needed in a short time. The main problem in launching them is slowing down their reaction so they won't explode, but will burn rapidly and smoothly. Most solid-fuel rockets have blow-out disks. These rupture, preventing the rocket from leaving the ground, if internal pressure builds up to the point where it may split the rocket's casing. A split casing can cause a rocket to go wild. Just before firing time, the rocket's igniter is installed. It is plugged into the firing circuit and set off electrically. This starts the propellant burning — and the rocket soaring.

Marianne Felice of St. Xavier Academy, Greenburg, Pennsylvania, writes:

Does malaria originate in man or in the mosquito?

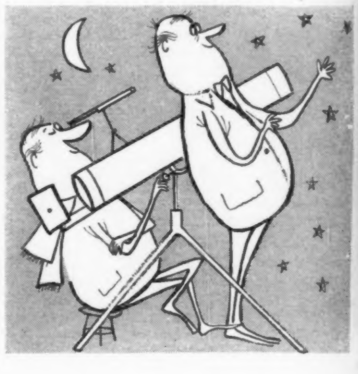
That's like asking, "Which came first, the chicken or the egg?" We cannot say definitely that malaria originates either in man or in the mosquito. The disease travels in a cycle that seems to have no beginning or end. Malaria is caused by minute parasites. These parasites enter and infect the female *Anopheles* mosquito when she bites a human being who is infected with malaria. (Only the female *Anopheles* is the vector, or carrier, of the disease. The male, which lacks the piercing mouth parts of the female, is a vegetarian.) Once inside the mosquito, the parasites find their way to the insect's salivary glands. There they remain until the mosquito bites a human being. The parasites enter the human being through the mosquito's saliva, settle in his bloodstream, and infect him with malaria.



Tony Foote of Mercer, Tennessee, writes:

Why is it that stars twinkle and planets do not?

The stars are so far away that all we can see of even the nearest star — apart from the sun — is a point of light. The earth's atmosphere, with its air currents, varying temperatures, and turbulences, affects that point of light. In consequence, it dims, brightens, and sometimes is entirely obscured from view. The result: a twinkle. In the case of the moon and the planets, which are relatively close to the earth, we see a disk made up of countless points of light. The light appears steady, because when some of the light points are affected by the earth's atmosphere others are not. But even the planets seem to twinkle when they are seen near the horizon, for their light is then traveling through a greater thickness of atmosphere.



Rudy Strohschein of Barrington, New Jersey, writes:

Can asbestos be melted?

There are several different types of asbestos. All can be melted. Their melting temperatures vary from 2,180° F. to 2,770° F. The most commonly used asbestos, chrysotile, loses its molecular water at a little less than 1,000° F. When the temperature is increased to 1,500° F., the chrysotile changes to another mineral, forsterite. At 2,700° F., it fuses, or melts.

Questions from readers will be answered here, as space permits. Send to: Question Box, Science World, 575 Madison Avenue, New York 22, N.Y.

The cars are safer . . . the roads are safer . . . so when you drive to the big game

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GENERAL MOTORS **A CAR IS A BIG RESPONSIBILITY—SO HANDLE WITH CARE!**

By Roy A. Gallant

Birth of the planets

From the earliest times, man has wondered how the planets and sun came into being, and, to a large extent the question is still unanswered

■ Prehistoric men must have gazed into the night sky with a sense of boundless wonderment. They must have asked themselves dozens of questions about the motion of the planets and stars, about eclipses, and about the phases of the moon. For most of these questions, early men found no answers. Lacking mathematics, they could have no idea of the size and great distance of the planets and stars. Without physics and chemistry, no man could know why stars shine or what they are made of.

Today, science has stripped the mystery from many of these questions. But nothing can strip away man's wonderment before the vastness of the heavens. And some of the most ancient questions remain unanswered: Where did the sun and the planets come from? How were they formed? We theorize, but we do not know for sure.

The first attempts to answer these questions took the form of myths. There are dozens of such myths from many countries, attempting to explain how the sun, earth, and life came into being. And, interestingly enough, these myths were the only answers until a short 200 years ago.

It wasn't until the 1700's that scientific efforts were made to explain the origin of the solar system. Then, as now, every major explanation of the birth of the planets stemmed from one of three hypotheses:

1. The planets came directly from the sun.
2. They were formed from a companion star of the sun.
3. Both sun and planets had their origin in a great cloud of dust and gas.

In 1755, the German philosopher Immanuel Kant published a paper on the general history of the heavens. He said that the sun and its family of planets were formed out of a huge cloud of dust and gas. Gradually, he said, the cloud began spinning; and as it did, it flattened itself so it had the appearance of a disk. Cause of the spinning, according to Kant, was a combination of two forces: first, the tendency of heavier matter within the cloud to move toward the cloud's center; and, second, the simultaneous tendency of the cloud to expand.

As the cloud continued spinning, individual gas and dust particles were attracting one another and forming into small, then larger and larger globes. As the matter packed itself tighter around the cores, the globes began generating heat. Eventually the globes became great, hot, molten spheres, which cooled over a period of millions of years — and became the planets with their moons.

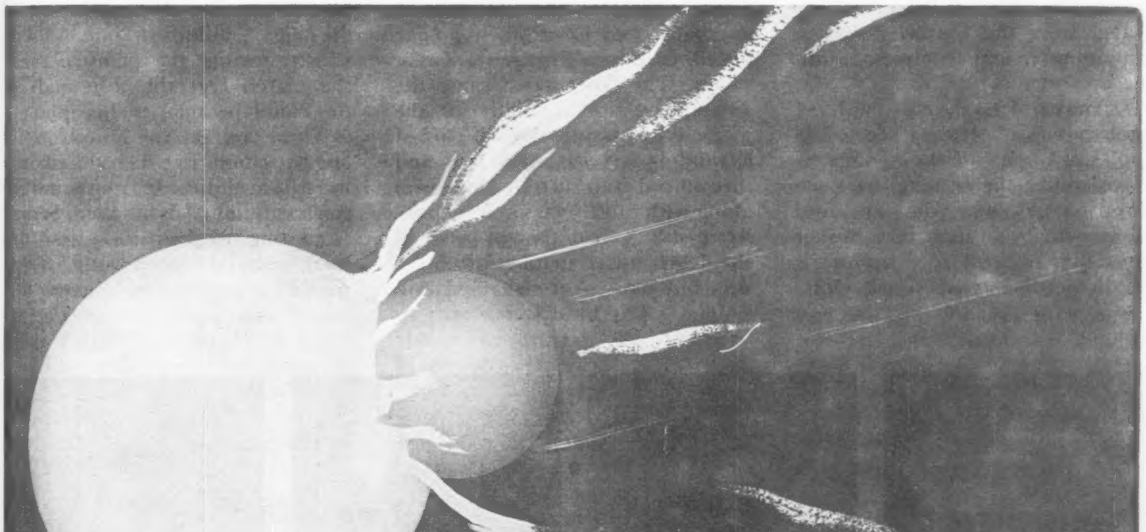
Although Kant's hypothesis was not widely accepted in the 1700's, today's scientists find considerable merit in it — with the exception of his explanation of the forces that set the cloud spinning.

In 1778, Comte de Buffon, the brilliant French naturalist, announced his "collision" hypothesis — a revised version of an account he had offered 34 years earlier. In Buffon's account, the sun was for many years without a family of planets. But one day, he said, a "comet" collided with the sun and splashed billions of tons of solar debris into surrounding space. Gradually the debris collected into globes, which began generating heat and eventually cooled into the planets. (In Buffon's time relatively little was known about comets. When he said that a "comet" collided with the sun he probably meant a foreign star.)

Another Frenchman, an astron-

Illustrations by John Polgreen from the book Exploring the Planets *by Roy A. Gallant, courtesy of the publisher, Garden City Books.*

According to Kant's theory, the sun and its planets formed out of a huge cloud of dust and gas. As the cloud spun and flattened, particles collected into globes, contracted, and generated heat. Long after, the molten planet-globes cooled.



'Collision' theory was put forward by Buffon. A comet, he said, had plunged into the sun, splashing billions of tons of solar debris into space. The debris collected into globes that, after generating heat, cooled into the planets we know.

omer named Pierre Simon de Laplace, in 1796 developed the "nebular" hypothesis to account for the planets' origin. It "explained" so simply many observable features of the sun and planets that it was widely accepted for about a century. His starting point, like Kant's, was a great cloud of dust and gas stretching beyond the present position of Uranus (the farthest known planet during Laplace's time). Gradually, he said, the cloud was radiating heat into surrounding space. This caused the cloud to contract and become dense. At the same time it was spinning and flattening into a giant disk. When the spinning reached a certain speed, the cloud threw off a great ring of gas and dust as the cloud proper continued shrinking. Over many years the ring collected into a globe, heated to molten matter, then cooled and became a planet. Each planet, Laplace said, was formed the same way — every time the shrinking disk of dust and gas threw off a ring, the ring condensed into a planet. And in the process, each embryo planet left its own rings, which condensed into moons. After the last ring separated from the central disk, the remaining matter contracted into the present sun.

Scientists of Laplace's time liked his hypothesis because it seemed to explain: 1) why all the planets revolve round the sun in the same direction; 2) why the sun and planets rotate on their axes in that same direction; 3) why the orbits of all the planets are nearly circular and lie in about the same plane; 4) why the outer planets are larger and have so many moons (supposedly, the first few rings would have been more massive than the later ones).

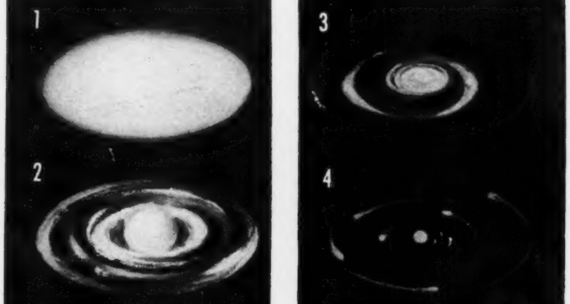
However, according to Harold C. Urey of the University of California, there are many objections to Laplace's idea — objections that should have been raised even during Laplace's lifetime. For example, if such a spinning disk had left rings, the rings would not have collected into globes; instead, they would have remained rings like those of Saturn. Then, too, if the ring idea were sound, the sun today would be spinning faster than all of the planets combined. But this is not the case; the sun rotates more slowly than nearly all of the planets.

In 1900, F. R. Moulton and T. C. Chamberlin, two American scientists, drew on Buffon's account for their own. According to their "planetesimal" hypothesis, a foreign star, X, once passed dangerously close to the sun, before the sun had acquired its planets. The foreign star came possibly as close as three million miles. During its approach, two great tides — one on either side of the sun — were raised. The closer star X came, the greater the tides. Finally, at the moment of passing, the top part of a tidal bulge was torn free and thrown out into surrounding space along with huge solar prominences. After star X had passed, some of the debris was drawn back into the sun, but most of it remained as a great flat ring circling the sun. Gradually, the ring material solidified into small globes called "planetesimals." Over many years, as the larger planetesimals circled the sun, they swept up the smaller ones and so grew into the planets. The moons of the planets supposedly were traveling just fast enough to escape being drawn into the planetesimal globes, but were not fast enough to escape satellite capture.

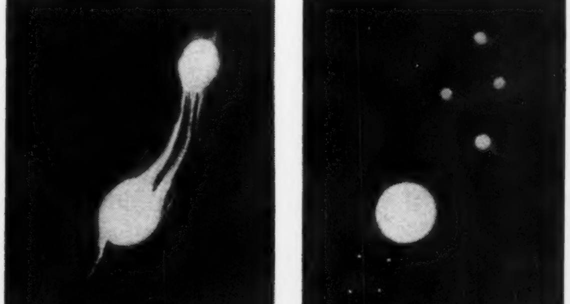
An interesting sidelight of this hypothesis, sometimes overlooked, is that what happened to the sun also must have happened to star X. Namely, that star X would have a planetary system of its own.

Eighteen years after Moulton and Chamberlin introduced their planetesimal hypothesis, two British astronomers — Sir James Jeans and Sir Harold Jeffreys — published their "tidal" hypothesis. This was not unlike the Moulton-Chamberlin idea. One difference was that, instead of a near miss, star X grazed the planetless sun. The second difference was that just after the grazing a cigar-shaped filament of gas, rather than a disk, reached between the two stars. Gradually the material in the thicker section of the cigar solidified into globes, which became the giant planets; the material at the thin ends of the cloud became smaller planets.

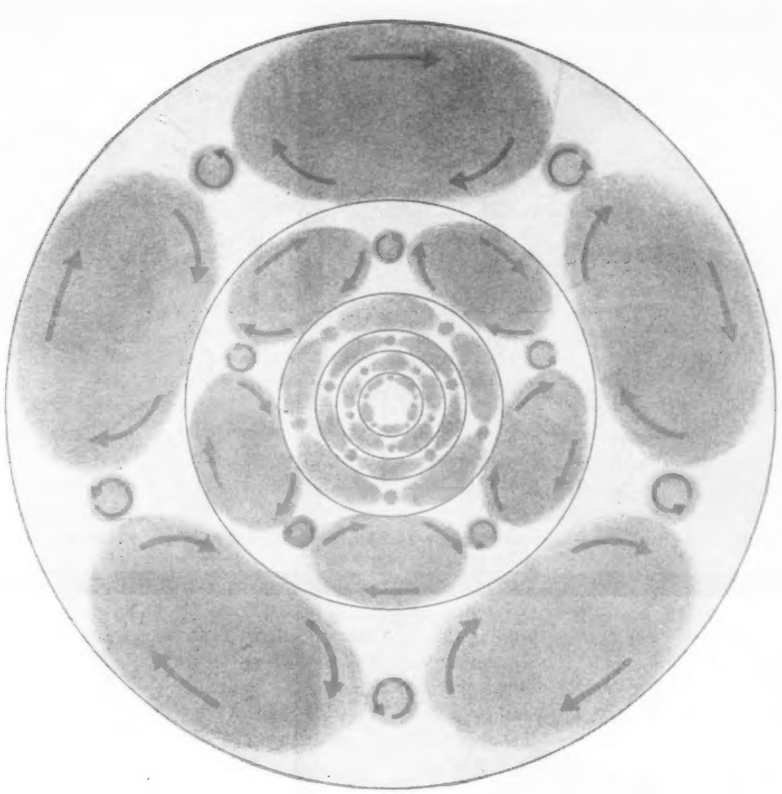
There are several objections to any hypothesis in which the planets were formed directly from solar (or star) material. Among them is this: According to Lyman Spitzer Jr., solar material ripped out of a star would be millions of degrees hot.



Laplace: spinning gas cloud (1) threw off giant rings (2), which became planets (4); remaining matter became the sun.



Moulton-Chamberlin: foreign star passing close to sun raised two tides. Gaseous bulge tore loose, condensed into planets.



Theory developed by Weizsacker supposes vast swirling cloud of dust and gas, which flattened in spinning. Whirlpools formed within disk, then 'roller-bearing' globes that condensed into planets.

There would not be time for it to cool and condense into a planet. Before this could happen the hot material would diffuse, spreading out into space.

Within the past ten years or so, two new hypotheses accounting for the planets have been offered, one by a British astronomer and the other by a German. According to British astronomer Fred Hoyle, the sun (itself a star) was once a partner in a double star system. In other words, the sun for millions of years had a companion star. One day the companion exploded. Most of its matter was hurled far out into space, but some was caught in the sun's gravitational pull. This matter remained around the sun and eventually settled as a great ring. Gradually the ring matter collected into giant globes many times larger than the present planets. They became so large, Hoyle says, that they began to break up; the larger chunks became the major planets, and the smaller ones became the minor planets.

Back to Kant?

At this point you may be wondering if there is any one hypothesis that stands head and shoulders above the others. Yes, there is. Many astronomers see great promise in a hypothesis developed by the German astrophysicist Carl von Weizsacker and revised by Gerard Kuiper, George Gamow, and others.

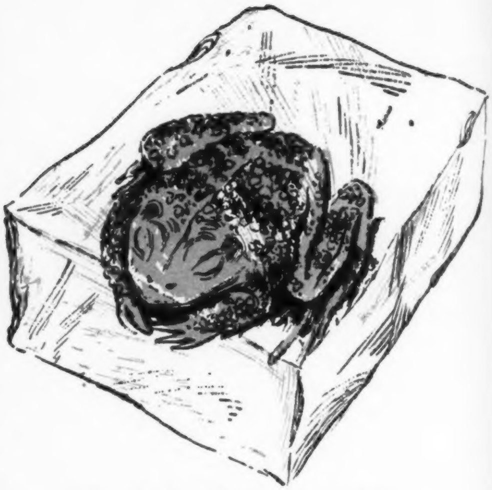
The Weizsacker description shows us a cloudy infant sun at the center of a vast, spinning cloud of dust and gas — not unlike Kant's dust cloud. Through time, hundreds of huge whirlpools formed within the disk. Where the whirlpools' edges brushed against each other, smaller "roller-bearing" globes of gas collected. Slowly these globes condensed into the planets, in the process developing individual gas and dust rings from which their moons were formed.

As promising as Weizsacker's idea appears to astronomers, it leaves many questions unanswered — questions which only time and more research may be able to settle. Kuiper, for example, makes this criticism: The planets, he feels, could not have formed directly out of the small roller-bearing globes. He says that these globes could not have lasted for more than 10 to 100 years — too short a time for planet formation. Kuiper does think, however, that the larger whirlpool globes were massive enough and lasted long enough for the planets to form directly from them.

Whether or not the Weizsacker hypothesis will pass the test of time is anyone's guess now. There is even a possibility that man will never know for certain how the solar system came into being.

Illustrated by William Bryant

Eastern chipmunk retires to its snug burrow in early autumn.



Because it is cold-blooded, the frog can survive weeks of being frozen solid in ice.

Bear cubs are born during winter sleep of mother bear. Here, bears emerge from their den.

Active in winter, deer often have hard time finding food under snow

By Joseph Wood Krutch

When the animal world goes to sleep

■ To Thoreau it was "that grand old poem called winter," but neither writers nor the general public usually speak so well of it. Ski enthusiasts excepted, few people ever exclaim "Winter has come!" in the tone of voice they reserve for the more popular seasons, and Shelley couldn't think of anything more favorable to say than that spring could not be far behind.

Snow, ice, and bitter winds seem to fall upon the living world like some irretrievable calamity and to leave nothing but ruin where trees had rustled and flowers bloomed. Even those to whom the love of nature is a dominant passion sometimes speak of "the dead of winter," and a winter landscape can indeed look like a lunar one — as though forever silent and never to live again.

But, of course, "dead of winter" is wrong. Even "sleep of winter" doesn't cover everything. But it does cover a great deal more. Though a few of the animals — mammals in particular — are wide-awake, most of them are, like most of the plants, quiescent — some lying motionless but awake; some in that half-sleep of the bear whose young are born while their mother dozes; some in that deep sleep called hibernation; many more locked in the deathlike suspension of all visible activity characteristic of the wintering egg, seed, chrysalis, or cocoon.

Even for the proudly technological human being, survival is to some extent a problem, and among animals there are few, if any, who do not either withdraw in some way from winter or face an intensified struggle for existence. The various devices by which winter is eluded or made endurable have been learned over a long period of time. At least all the higher animals must have got their start in regions where winter never came, and, if the evolutionists are right, slowly worked out their astonishingly varied survival techniques as the rigors of the weather increased.

What is true of the animals is true of the plants, too — but with differences. And if we leave the plants aside for the moment to consider only that half of animate creation with which we are closely allied, we may be humiliated to discover how little man himself has added to the techniques developed by his humble cousins. One of them — hibernation — he has abandoned, and one — the great, Promethean discovery that fire can be started and controlled — is his alone. Otherwise he does only what other animals were doing many millenia before his appearance — building shelters, producing heavier clothing, storing food, or simply going away to some region where it doesn't get so cold.

Migration mysteries

This last maneuver is called "taking a winter vacation" when men adopt it and "migration" when applied to animals. Many of the latter make minor shifts from a cooler spot to a warmer, but migration on any large scale is practiced almost exclusively by the hoofed animals (like the caribou), some butterflies, and, pre-eminently, by the birds. Some birds — the chickadee, for instance — are found the year round in the same regions, of course, and some, like the robin, may move relatively short distances; but many others, like the oriole and the tiny hummingbird, go all the way to Central or South America, while one frantic world traveler, the arctic tern, spends the northern summer in the arctic and the southern summer in the antarctic.

Why do they do it and how do they do it? No problem of animal behavior has been more discussed or still involves more mysteries.

How, having no calendars, do birds know when to take off? Experiments seem to prove pretty conclusively that the lengthening and shortening of the days, rather than any change in temperature, is the signal. How they find their way — the great question — is still disputed. As late as the eighteenth century, an educated man could still believe that swallows spent the winter beneath the mud of pond bottoms. What they actually do is no less remarkable, even if confusion exists as to its whys and wherefores. Our chimney swifts, for example, seem to travel, one and all, to Peru. Why Peru? Well, perhaps only for the same reason that some human beings always vacation in the same spot: "Our family has been going there for years."

What of the many kinds of animals which, like most human beings, are unable to manage a winter vacation? Deer, foxes, weasels, rabbits, and wildcats are among those who store no food, and some of them — the deer especially — may have a pretty hard time living upon what they can find by scraping away the snow. In the water under the ice muskrats find food the year round, and the prudent squirrels and field mice lay up winter stores. (The field mouse also supplements his stores by foraging as he makes his way along the tunnels he digs through the snow.) Gray squirrels, too, are active, though in really inclement weather they may remain for days curled up snugly in their leafhouses high in some tree.

If all these animals as well as the wintering birds can "take it," why can't others not too distantly related? Why is it that the flying squirrel is active all winter, while the Eastern chipmunk retires in autumn to a well-stored burrow and stays there almost continuously, even, in colder climates, sinking into dormancy? And why do the woodchucks, ground squirrels, and brown bats fall into complete hibernation?

No animal habit is stranger than

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hibernation. It is not the same as sleep, no matter how deep. It seems half-way to death, and one wonders if it could have occurred first with animals that barely escaped death in the course of increasingly rigorous winters. Men on the point of freezing are said to grow drowsy, and that is exactly what happens to the hibernators as the cold comes on.

The process begins at about 50° F. The animals grow sleepier and sleepier and their body temperature drops, because the success of the maneuver depends upon the fact that they cease to be "warm-blooded." Thus the temperature of a hibernating woodchuck may fall to about 37° F. His rate of breathing declines from a normal of thirty times a minute to as little as once in five minutes. His heart may beat only four or five times per minute, and he may remain completely motionless for days on end.

Violent wakening is likely to kill him, but wakening at the normal time is rapid. His metabolism, which was very low, rises to a fever pitch, and before long the woodchuck, formerly hardly alive, is again as good as new.

It used to be said that no bird ever hibernates — perhaps because it knows the better trick of going south, if necessary. But only a few years ago it was discovered that at least one bird does, a southwestern relative of the eastern whippoorwill, who tucks himself into a cranny and stays there in the deep sleep of real hibernation. Truly a most unbirdlike habit.

The ability to keep warm blood at a constant temperature, by means of a sort of internal thermostat that opens the metabolic draft when necessary, is a characteristic of mammals and birds alone. Its obvious advantage is that it enables the animal to be as lively in cold weather as in warm. Cold-blooded reptiles and amphibians, on the other hand, move and indeed live at a variable rate, which grows more and more sluggish as the temperature falls. The same is true of many insects, and you can, if so inclined, tell the temperature on a summer evening by listening to the snowy tree cricket, whose chirps may be translated by a simple formula into degrees Fahrenheit. (The formula: $T=N/4+40$, where T equals temperature, and N stands for the number of chirps per minute.)

But warm-bloodedness has its disadvantages, too, of which the most obvious is that cold can reach a point where the blood temperature can no longer be maintained. Then the animal will die unless he either migrates to a warmer place or, like the few hibernators, has learned the trick of becoming, temporarily, cold-blooded. For the normally cold-blooded, it is all very much simpler. A frog may be frozen solid in a cake of ice for weeks at a time and come back to life when the ice thaws out.

The frog is an extreme case, but many of the humbler creatures who disappear from the scene in autumn or winter are simply somewhere out of sight sleeping the inclement season away. Of those insects who pass the winter in the adult stage, millions are tucked away in crannies, in or under the bark of trees, and millions more have taken refuge beneath a ground cover of dead leaves. To the latter creatures, a snow blanket is so great a help that when the surface of the bare ground is nearly zero, two inches of soft snow may keep the temperature a few inches belowground just above freezing.

Insects and plants

"Not dead but sleeping" is the most fitting description of the mood of the animal world in winter. But, of course, some animals do die in their sleep, and there are others to whom the end of summer is always the end of the world. This is true of a great many, but by no means all, insects. The female lays her eggs and dies, much as an annual plant produces its seed before it withers. The seeds of plant and animal alone survive.

Most people probably know rather more about plants in winter than they do about animals. Even non-gardeners are aware that some plants are annuals, which would live for but one summer whether winter ever came or not, and that others are perennials, some of them green during the fiercest blizzards, others merely losing their leaves, and still others retiring underground to a sort of hibernation in root or tuber.

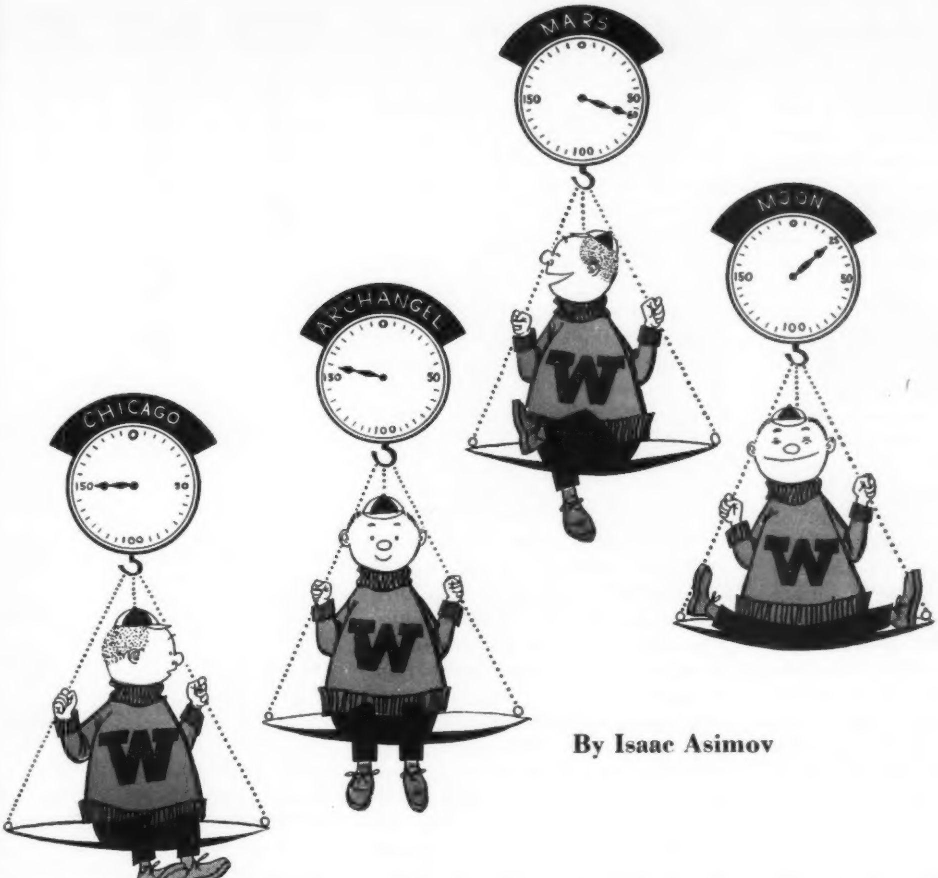
Superficially, these methods of survival seem roughly analogous to those adopted by animals. But the reason that many plants must take defensive measures is not the same. They are not warm-blooded or cold-blooded; indeed, they are not blooded at all, and while they have many different reactions to changes of temperature, the most obvious cause of death when freezing sets in is the simple fact that ice crystals forming inside the leaves penetrate the living cells and destroy them.

Woody plants can meet that problem by sacrificing their leaves and exposing to the air only the dead covering of bark; herbaceous plants do so by dying as far down as the protected root.

Perhaps the most striking difference between plant and animal adaptation to winter is the fact that to many plants winter is not merely something to be endured, but something that is necessary to their existence. A woodchuck kept awake in warm quarters all winter will not die because he did not get his accustomed sleep. On the other hand, many perennial plants must go into winter dormancy or they will die.

Also, many seeds will not germinate unless they have been frozen at least once. And many buds formed in the late summer or autumn will not unfold in spring unless they, too, have been frozen. Bring a bare branch of forsythia into the house in autumn, and the buds will never open. Bring one in in January or February, after it has been well frozen, and they will — long before spring has come.

Winter, then, is as good a time as spring to observe the ingenuity of nature and to marvel at the many different ways — sometimes one is tempted to say all the possible ways — in which a given problem is solved. Why do some plants and animals use one and some another? Evolution gives part of the answer when it stresses "adaptation." But why, in a given instance, this adaptation rather than another? It can hardly be just to make the world more interesting. But that is exactly what it does.



By Isaac Asimov

The fickle measurement-weight

Move an object from one place to another, and its weight may change, due to variations in gravitational force. That's why scientists deal with the fundamental property called mass

■ Do you know that you would weigh less in New York than in Chicago? That if you were whisked to various parts of the world, your weight would change accordingly?

Let's suppose that a very delicate weighing machine showed that you weighed exactly 150 pounds in Chicago. In New York City, you would weigh one thirtieth of an ounce less than 150 pounds. In Madras, India, you would weigh just about 5 ounces less than 150 pounds. And in Archangel, on the Soviet Union's northern coast, you would weigh 5 ounces more than 150 pounds.

In this "Age of Space," moreover, there are even more extreme cases of weight change that you ought to consider. If you weighed 150 pounds in Chicago, you would weigh about 25 pounds on the surface of the moon and about 60 pounds on the surface of Mars. On the other hand, you would weigh about 400 pounds on the surface of Jupiter. And, to top it off, in a satellite or space station moving freely in orbit, your weight would be just about zero!

Obviously, though your weight may vary, the amount of matter composing your body stays the same wherever you are. The amount of matter contained in an object is called its *mass*. Your mass remains the same whether you are in Chicago, New York, Madras, or Archangel; whether you are on the earth, on the moon, on Jupiter, or on a satellite orbiting the earth.

But, then, if your mass stays the same, why does your weight vary? Why does a scientist find himself forced to talk about mass instead of about weight? Why does he prefer to say that one object is "more massive" than another, rather than "heavier"; or "less massive," rather than "lighter"?

Well, weight doesn't actually measure the amount of matter in the object being weighed. It measures the pull of the earth's gravitational force upon the object. The simplest way of measuring that pull is to suspend the object from a spring and measure the distance that the spring is extended. (Such a weighing instrument is called a

spring balance; see drawing right.)

If two identical masses are attached to the spring, it will be extended just twice as far as it will by a single mass. Five such masses will pull down the spring five times as far as a single mass will.

In general, in any one spot on the earth, the weight registered on a spring balance is directly proportional to the mass of the body being weighed. The weights registered by different objects will vary in direct proportion to the way their masses vary.

But, in that case, why does weight vary as you move from one spot on earth to another, even though mass does not? The reason is this:

The gravitational attraction of the earth upon an object (an attraction that determines the object's weight) depends on more than just the mass of the object. It also depends, for instance, upon the distance of the object from the center of the earth. The farther the object is from the center of the earth, the weaker is the gravitational pull upon it and the less is its weight — even though its mass does not change.

An object at sea level is roughly 3,950 miles from the center of the earth. The same object, moved to the top of Mount Everest, would be 3,956 miles from the center of the earth. Gravitational force would be slightly weaker there than at sea level. If the object weighed 100 ounces on a spring balance at sea level, it would weigh only 99.7 ounces at the top of Mount Everest.

To complicate matters, the earth is not an exact sphere. It is slightly flattened at the poles. An object at the North or South Pole is 3,950 miles from the earth's center. But an object at the equator is riding atop the earth's "equatorial bulge" and is 3,963 miles from the center. This means that the earth's gravitational force is greatest at the poles (where objects are closest to the earth's center) and gradually lessens as one travels toward the equator. Moreover, because of the earth's spin, there is a centrifugal force countering gravity. This accentuates the loss of gravitational strength as we move toward the equator.

As gravitational force weakens, weight decreases. For instance, suppose that an object when weighed by a spring balance at the North Pole shows a weight of just 100 ounces. Its weight at other points on the earth is as shown in the accompanying table.

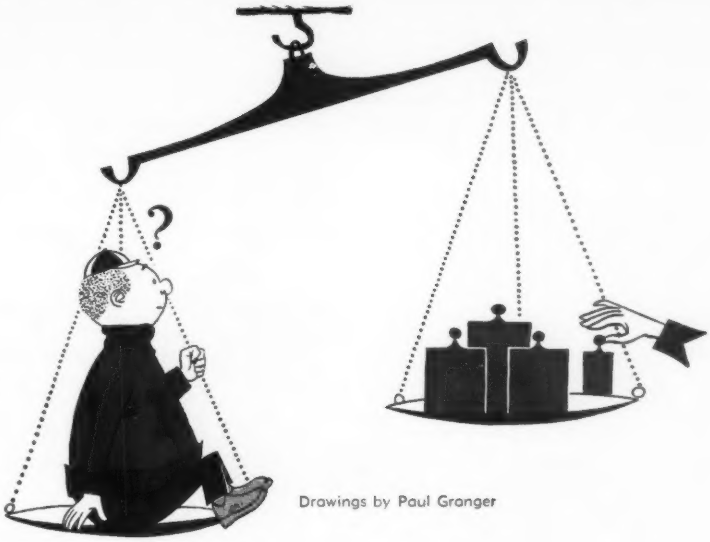
As you see, the difference in weight between an object at the poles and at the equator amounts to only half an ounce in 100 ounces, or one-half of one per cent. This is quite enough, however, to throw off calculations being made with delicate measurements.

Suppose you have two objects, A and B. At the North Pole, A weighs 100 ounces, and B weighs 99.8 ounces. They show just these weights on a spring balance. A is therefore both heavier and more massive than B. Now move A to the equator and leave B at the Pole. A spring balance at the equator now shows A's weight to be 99.47 ounces. Though A is still more massive than B, it is now the lighter of the two.

The point is that weight varies with the position of an object on the earth — with its latitude and with its height above sea level — because gravitational attraction varies. But mass, which represents the quantity of matter the object contains, does not vary with position. It is therefore the more fundamental property. An object has just as much matter in it at the North Pole as at the equator, and just as much matter at the top of

VARIATIONS OF WEIGHT WITH LATITUDE

LATITUDE	SOME CITIES AT THAT LATITUDE	WEIGHT AT SEA LEVEL
90° (the poles)		100.00
60°	Juneau, Leningrad	99.87
50°	London, Warsaw	99.78
40°	Peiping, Philadelphia, Madrid, Melbourne	99.69
30°	Shanghai, New Orleans, Cairo, Valparaiso	99.60
20°	Mexico City, Bombay, Rio de Janeiro	99.53
10°	Caracas, Addis Ababa, Lima	99.49
0° (equator)	Singapore, Quito	99.47



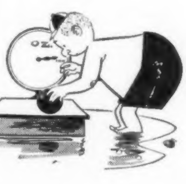
Drawings by Paul Granger

Mount Everest as at sea level, regardless of how its weight varies.

It has been agreed by scientists to consider the weight of an object under a certain set of conditions as its *standard weight*. These conditions are that the object be weighed at sea level and at a latitude of 45°. The weight there is the standard weight.

Of course, to weigh an object a scientist isn't going to rush to a place that is at sea level and at 45° latitude. He can weigh the object with a spring balance at any latitude and at any height above sea level. His handbooks will give him figures that he can use to convert the weight he gets to standard weight. Naturally, he will have to know what his latitude and altitude are and he'll then have to start figuring. It would be nice, therefore, if he could use a weighing instrument that would not require this sort of correction.

So, instead of a spring balance,



he uses an *equal-arm balance*. Imagine a horizontal rod suspended from a beam by a hook through its exact center. From each end, at points equally distant from the point of central suspension, are hung two equal pans. If a weight is put in one pan, that pan will sink. If there are weights in both pans, the pan with the greater weight will sink.

If, however, the weights in both pans are exactly equal, neither pan will sink; they will remain in delicate balance. (Very accurate and refined instruments of this sort, used to measure small masses in chemical analysis, for instance, are commonly called *analytical balances*.)

Such a balance doesn't measure the gravitational pull on one object alone. It measures it on two objects and compares the two, telling you which is heavier. But, in using a balance, you are interested in the point at which the pulls on both sides are equal, the point at which neither side is heavier.

You begin, for instance, by placing an object of unknown weight in the left pan. You then place a series of known standard weights in the right. You find that when you have placed 100 ounces of weight in the right pan, the two pans balance and come to a level. The unknown object, therefore, also has a standard weight of 100 ounces.

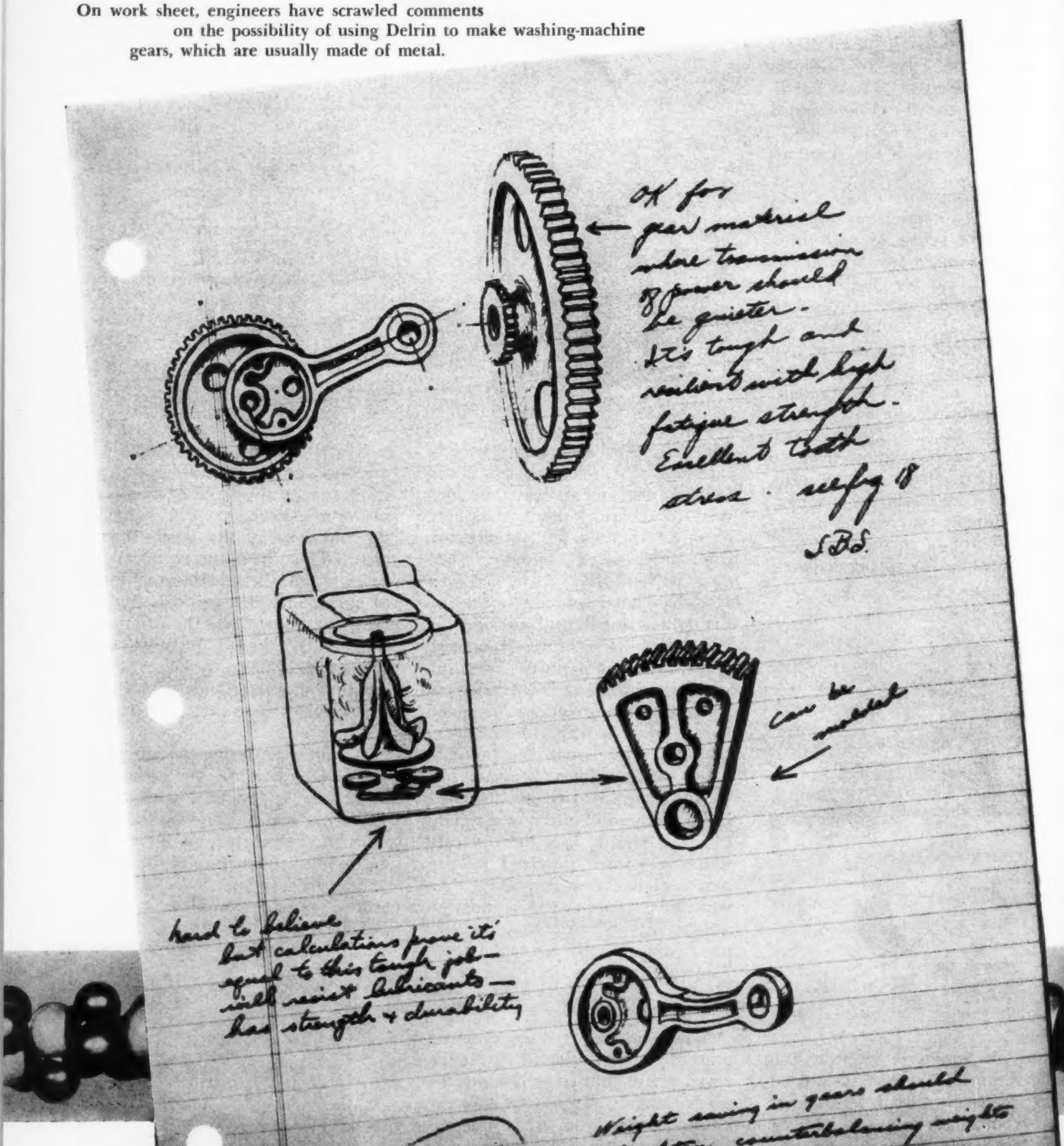
Now, you see, it doesn't matter that the gravitational attraction varies with your position on the earth's surface. It may be that the known weight you are using has a standard weight of 100 ounces, but that at your latitude and altitude it weighs only 99.8 ounces. It is 0.2 per cent lighter than it is marked as being. But then the object of unknown weight is also 0.2 per cent lighter than its standard weight, so the two still balance.

If a 100-ounce weight balances an object of unknown weight at sea level, it will also balance it on top of Mount Everest. If it balances the unknown at the poles, it will also balance it at the equator. In other words, the gravitational force of attraction changes equally for both the known and the unknown weights. We know, therefore, that the masses of the two objects — the amount of matter they contain — are equal.

Weight is confusing enough when we deal with it on the surface of the earth. It becomes more so, in this age of space, when we consider objects at great heights above the earth or on the surface of the moon or planets. And on man-made satellites, weight completely disappears. Matters that seem natural on earth are turned topsy-turvy.

[*In* SW, *February* 24: "*Where Weight Disappears.*"]

On work sheet, engineers have scrawled comments on the possibility of using Delrin to make washing-machine gears, which are usually made of metal.



Chemists have custom-built a new kind of plastic — one that is

Neither soft nor brittle

By Edmund H. Harvey Jr.

■ Sometime next summer, you will begin to hear about a new plastic called "Delrin," made by E. I. du Pont de Nemours and Company. And not long after that, you may meet Delrin in the form of an aerosol container, a comb, dinner plates and tumblers, football cleats; in the gears of a car speedometer or windshield wiper; or in heavy-duty machinery, appliances, plumbing, and hardware.

Delrin is not just a new variation of an old substance. It's true that each plastics producer is likely to have its own special name for a plastic that is not much different from one made by many other companies. Polyethelene, one of the most common plastics, has twenty-five or more different trade names. Polystyrene, another major plastic, has about twenty. But it's also true that there are some twenty-five essentially different kinds of plastics now being produced in quantity. They differ in their basic chemical formula. Delrin will be one of these. And Du Pont is quite certain that Delrin's properties will make it better for some uses than any plastics now available.

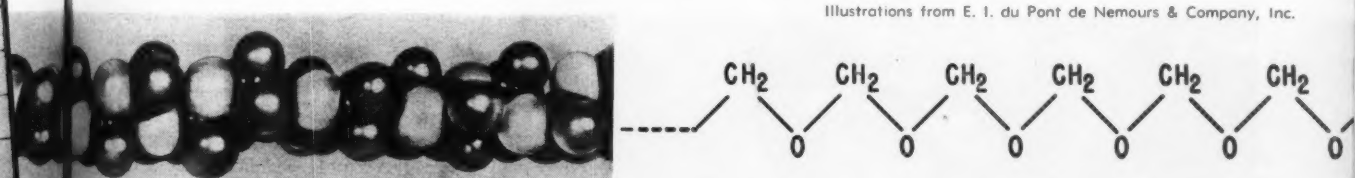
Polymers to plastics

In a very real sense, the plastics industry is based on certain organic molecules — the molecules of compounds containing the element carbon. Delrin's basic chemical unit, for example, is the molecule of the compound CH_2O. This is the formaldehyde molecule. In polyethelene, the basic unit is ethelene, C_2H_4. Many of these basic molecules may be linked together to form a more complex larger molecule, which is called a polymer. Polymers can be found in nature — in a cellulose, for example. Or they can be made by the chemist, using heat, pressure, and certain catalysts This process of making polymers — polymerization — is the key to the production of all plastics.

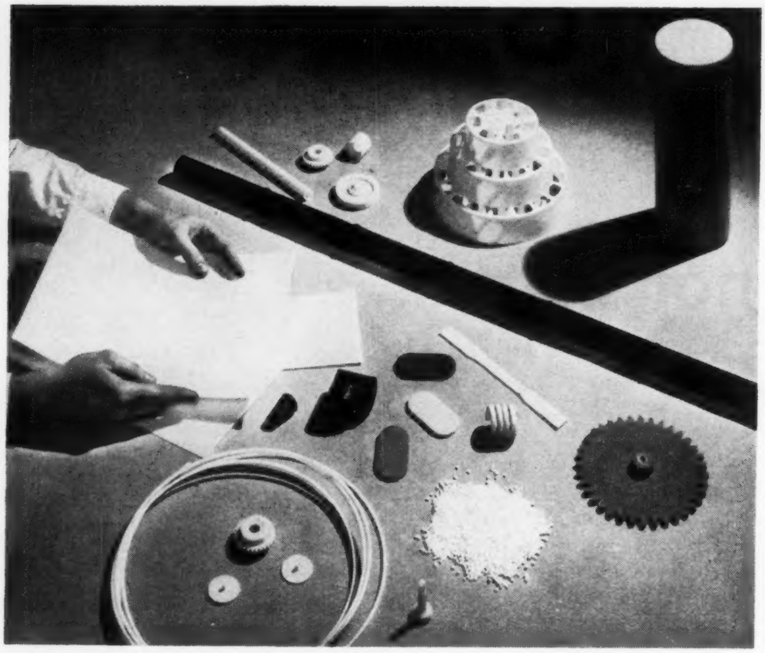
A polymer can be many hundreds, or even thousands, of times bigger and heavier than the original carbon-compound molecule. But it is still a true molecule, with its hundreds or thousands of simpler molecules (or monomers) chemically chained together. In most polymers, all the monomers are identical to one another. Delrin, for instance, consists primarily of a given number of CH_2O molecules chemically locked together. But in some man-made polymers, two different kinds of monomers are united. The result is called a co-polymer.

All plastics are made up of millions of closely packed polymeric molecules. A polymeric molecule is the smallest unit of a plastic. But

Illustrations from E. I. du Pont de Nemours & Company, Inc.



Delrin is made of long polymers, each of which looks like a string with beads clustered around it (*above, left*). It is a big molecule, averaging more than 1,000 CH_2O units bonded together as shown (*above, right*).



Mechanical parts made of Delrin have been tested in a wide range of rugged jobs. Parts shown above include gears, connecting rod, bearings, bushings, slides, cams.

Not only stockings, but many automobile parts are made of nylon, a prominent plastic. Shown above are gears for speedometers, for windshield wipers, for radio antennas, etc. In 1959 automobiles, almost 250 different parts are made of nylon.

if all plastics are made up of polymeric molecules, it doesn't follow that all of these molecules can be built up into usable plastics. Some polymers are so unstable that they have never yet gone beyond the laboratory. And whatever the polymer, it's always a long time from its first synthesis in the lab to its appearance as a commercial plastic.

Formaldehyde polymers

Take the case of Delrin and the formaldehyde polymers. Formaldehyde polymers were first prepared in the laboratory in 1859. They were "small" polymers with a low molecular weight, and they were very unstable in the presence of heat or of acids and bases. Nobody paid much attention to formaldehyde again until the 1920's. Then a German chemist named Dr. Staudinger succeeded in preparing a polymer of relatively high molecular weight from purified liquid formaldehyde. Dr. Staudinger found that this polymer exhibited some mechanical strength. But at normal temperatures, the polymer lost its toughness and eventually decomposed, much as ice would melt above 0° C. Dr. Staudinger was interested only in the polymer structures and not in practical plastics. So there the matter rested until the early 1950's.

The formaldehyde polymer caught the eye of Du Pont research chemists because it was *almost* a promising plastic material. Its glaring drawback: an extreme sensitivity to heat. Du Pont chemists knew that the trouble probably lay in the way monomers of CH_2O were linked together to form the polymer. The link was between carbon atoms and oxygen atoms (see diagram on page 17). This has always been known as a weak bond, liable to be disrupted in any number of ways. About 1951, Du Pont chemists and chemical engineers began an all-out research effort to find how to improve the stability of the polymer chain.

Just how they did it is a closely kept company secret. But we can be sure that the formaldehyde polymer was subjected to hundreds of different combinations of heat and pressure. There was undoubtedly a search for the perfect catalyst —

one that would set off and control polymerization at exactly the right rate. Formaldehyde polymers were probably refined to a purer state than they ever had been before to remove any stray chemical impurities that could affect the chemical linkage. Perhaps other monomers were involved.

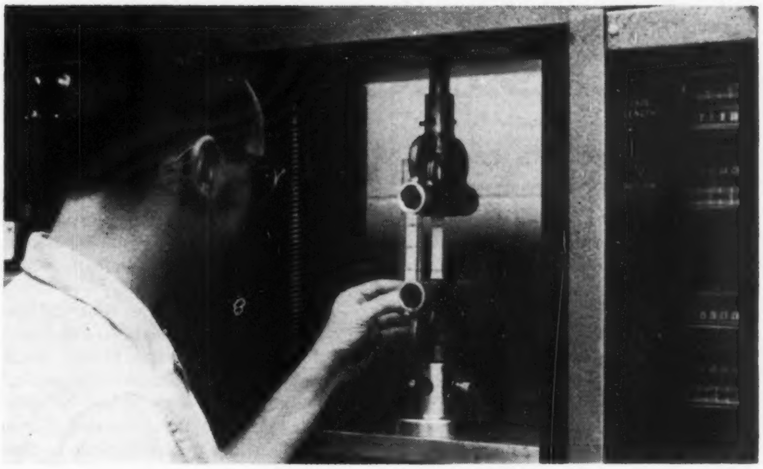
Altogether, Du Pont figures it spent 300 man-*years* of research before it turned out the first sample products made of Delrin. And even then these early test products — dishes, gears, and so forth — were pretty crude. They were pocked, splotched, and didn't have uniform strength. Eventually, about 1957, Du Pont's chemical engineers solved the big problem of producing high-quality Delrin in bulk. And they had already learned a great deal about how the plastic had to be handled when it was being processed and finished into end products.

Probably the most unique physical characteristic of Delrin is the fact that it is hard and rigid without being brittle. Most plastics lose their resilience as they are made harder, or vice versa. But Delrin has *both* high rigidity and high resilience. Or, as Du Pont puts it, Delrin is both strong and tough.

What gives Delrin its special properties? The answer lies in the formaldehyde polymer chains themselves. In Delrin, a single polymer chain — one big molecule — has a molecular weight of more than 30,000 and averages more than 1,000 CH_2O units. It has a long, stringy shape. These chains of CH_2O have a tendency to line up and cling tightly together, forming a crystal. In turn, the crystals fit together almost as tightly as a jigsaw puzzle.

All these factors — the high molecular weight of the formaldehyde polymer, its elongated shape and its ability to pack closely into a dense crystal, and the tight packing of the crystals — make Delrin an extremely dense and solid plastic. It is invulnerable to all but the hardest knock and the heaviest load.

But just as Delrin's physical properties make it suitable for certain uses, the properties of other plastics make them valuable for other purposes. So you can rarely say that one kind of plastic is *better* than another. It may be better for a specific task, but that's about as much as you can safely say. Some jobs call for a very hard, rigid plastic. Others for a softer, more pliable plastic. And so on.



Bar of Delrin is tested by Du Pont engineer for such mechanical properties as tensile strength and resilience. Tests are made under rigidly controlled conditions.

One of the ways manufacturers classify plastics is by dividing them into two general categories: thermoplastic and thermosetting. Thermoplastics can be heated and cooled, softened and hardened, shaped and re-shaped, without losing their original properties. Delrin is a thermoplastic; so are polyethelene, polystyrene, nylon, and the cellulosics. Thermosetting materials, on the other hand, can't be re-shaped once they have been molded into a given shape. Heating won't soften them, any more than heating will re-soften a hard-boiled egg. Thermosets include the phenolics (used for TV cabinets, radio-tube bases, etc.), the amino plastics (used in Melamine dinnerware, stove knobs, buttons, etc.), and several other families of plastics.

A plastic like Delrin is usually produced in one of three forms: as a liquid, as a powder, or in granules. Though we tend to think of plastics only as solid objects, the non-solid forms are also true plastics. Nylon (basically a polymer of hexamethylene diamine and adipic acid) is still nylon whether it's a liquid, powder, fiber, or solid.

When the liquid, powdered, or granular plastic leaves the production line, it goes to a processing plant. There it is processed into molded solids or into sheets, films, rods, filaments, or tubes — depending on the destined end-use. Nonplastic materials such as paper, cloth, hemp, and, most important, glass fibers may be used to reinforce or modify the raw plastic.

Plastics have become solidly entrenched in our daily life. And there are two good reasons for believing that we'll be using more and more plastics in more and more ways in the years ahead. First, the primary raw materials of plastics — air, water, salt, and natural gas — are virtually inexhaustible. Second, the possibilities of man-controlled polymerization are almost limitless. There are innumerable combinations and methods that have not yet been tried, and probably a great many more that have never been considered. This should mean a steady flow of new plastics, capable of being used in ways we just can't imagine now.

The time may come, for example, when the entire engine of a car or plane may be built of plastics, right down to the components in direct contact with high combustion. Already, the fan — not the fan belt — of one European car is made of solid nylon, and various tubing in American cars is either made completely of plastic or is plastic-treated.

Science in the news

AAAS scientists report on their achievements

Scientists reported their work to scientists at the annual meeting of the American Association for the Advancement of Science in Washington, D. C. Some of the newsworthy findings:

● A revolutionary new theory of the Ice Age. Recent evidence gathered by a scientist indicates that there was only one period of glaciation, when a vast ice sheet covered the northern part of North America. Previously, scientists had thought there were four distinct advances and withdrawals of glaciers during the Ice Age. The new theory would shorten geological history and eliminate the so-called interglacial periods.

● For brief periods, man can stand temperatures of up to 500° F., Air Force doctors reported. They "baked" human volunteers in specially constructed ovens to determine their heat tolerance under space-flight conditions. Results showed that man can tolerate greater heat intensity than was suspected. Another space experiment revealed that man could withstand the stresses expected in the launching and return of a space vehicle, if he were positioned this way: seated, facing forward with knees flexed, and leaning slightly in the direction of acceleration.

● Insecticides are doing more harm than good. DDT and other chemical insect-killers are destroying fish and other aquatic animals. Insects are fast building up immunities against the chemicals. Moreover, a scientist warned, the victims of insecticides are providing food for aquatic snails that often carry parasites responsible for serious diseases in man.

● Plant life exists on the planet Mars. Observation through the 200-inch Hale telescope revealed vegetation in areas that had seemed to be barren in earlier studies. Further evidence that lower forms of plant life can exist on Mars came from Air Force scientists. They had grown fungi and bacteria under conditions believed similar to those on Mars. Other scientists reported on the dangerous and the useful implications of micro-organisms in space. Harmless minute organisms carried from the earth might mutate (change their characteristics) in space and become hazardous to human health. But micro-organisms might also be beneficial. In the form of algae — using the process of photosynthesis — they could re-cycle a space vehicle's air supply, removing carbon dioxide and adding oxygen. Grown on human wastes, algae could also provide food for the space man. Algae, capable of multiplying at a rapid rate in a short time, are the most promising space "food" so far.

● Peaks as jagged as those of the Rocky Mountains have been discovered on the floor of the Arctic Ocean. Scientists traced their profile by using sound waves generated by explosions. Also discovered: a plateau stretching from the northernmost tip of Canada to Eastern Siberia. Its sides plunge to depths of from 10,000 to 15,000 feet.

● The use of satellites as astronomical observatories and navigational aids was forecast by Navy scientists. Satellites orbiting beyond the earth's atmosphere, for example, could carry huge spectrographs and telescopes to analyze ultraviolet radiation from the sun, from interplanetary space, and from the Milky Way. These rays are largely blocked by the earth's atmosphere. A satellite could also be used by ships and aircraft to fix their positions. This would eliminate their dependence on radio beacons.

● Two sharply defined bands of radiation, rather than one, girdle the earth. The first is between 1,400 and 3,400 miles from the earth's surface. The second lies between 8,000 and 12,000 miles out. Between the two belts, at about 6,000 feet, radiation intensity drops. Here a human could safely orbit in a lightly shielded satellite. Dr. James Van Allen of the State University of Iowa received the American Astronautical Society's Space Flight Award for these findings. They were based on data from the Pioneer III moon rocket.

● Music has been composed by an electronic computer at the University of Illinois. Called Illiac, the machine mastered highly complex musical techniques in its composition, "Illiac Suite for String Quartet." Another machine, invented at the Westinghouse Electric Corporation, received the AAAS Industrial Science Achievement Award. The machine, called Opcon, can duplicate the behavior of an informed human being in controlling industrial output. Scientists reported Opcon capable of discovering for itself differences between its own right and wrong decisions. And it reportedly can make impartial judgments based on its experience. Opcon's behavior is said to contrast sharply with that of machines that can respond only in fixed ways to situations planned for them.

Mechta only one step in Soviet space plan

Russia's man-made planet, Mechta, now orbiting the sun, is but one link in a chain of carefully planned space explorations. So far, the explorations have followed a program described last year by a Soviet scientist. There is strong evidence that they will continue to do so. This and recent Soviet hints give an indication of what space moves Russia will soon make.

First link in the space-exploration chain was Russia's three Sputniks, launched with successively more powerful rockets and staying in orbit for successively longer times. The rocket that launched the 3,245-pound Mechta was even more powerful. American scientists estimate that its weight at launching was 250 tons. The rocket's last stage — first called Lunik, then Mechta — sped past the moon, broke free of the earth's gravity, and entered an orbit around the sun. It thus became the first man-made minor planet (or asteroid). Its nearly 800 pounds of instruments measured cosmic rays beyond the earth's magnetic field, radioactivity around the moon, and other properties of space.

With this data, Soviet scientists say they are ready to add the next link to the chain: putting a vehicle into orbit around the moon. The vehicle may carry a dog, so that the effects of a long space flight on an animal may be tested. It will probably have a television camera or "scanner" to send back images of the moon's unseen side.

Soviet space plans also call for attempts to:

Launch a manned rocket or satellite sometime this year. Russian rockets are powerful enough to do this. And the Russians claim their scientists have conquered two barriers to manned space flight: re-entry into the earth's atmosphere and stabilization of a vehicle in space.

Launch a satellite that will become part of a space station. The satellite's payload will probably consist mostly of rocket fuel. Combined with later satellites, it would be used as a way station for interplanetary rockets.

Send rockets to Venus and to Mars. The Venus attempt is likely to be made about June 8. The planet's position in relation to the earth will then be most favorable to a launching attempt. Mars will next be in the most favorable position on October 1, 1960.

Tiny atomic generator will aid space travel

A five-pound atomic generator has solved a problem that has long puzzled space scientists: how to make a lightweight, long-lived auxiliary power source for space vehicles. The atomic generator is fueled by radioactive isotopes. It can produce electricity twenty times more efficiently than any other method.

The grapefruit-sized device uses the thermocouple principle. In this principle, electricity is generated when the junction of two dissimilar metals is heated. In the atomic generator, heat supplied by radioactivity is converted by a thermocouple into electricity. The generator's lightness, long operating capability, and absence of moving parts make it ideal for use in space vehicles or anywhere where small sources of electricity are needed. It also works well in cold weather. Unlike conventional batteries, its efficiency goes up when the temperature goes down.

The tiny device could have kept President Eisenhower's voice broadcasting from our Atlas satellite for a full year. In contrast, the satellite's twenty pounds of batteries lasted only eighteen days.

The new generator is called Snap III, since it's the Atomic Energy Commission's third project to develop a system of nuclear auxiliary power. It can be used not only in space vehicles, but to track hurricanes and to aid in air and sea navigation. Further refinements, say AEC officials, could reduce SNAP's weight from five to three pounds.

Atomic scientists tangle with radioactive seaweed

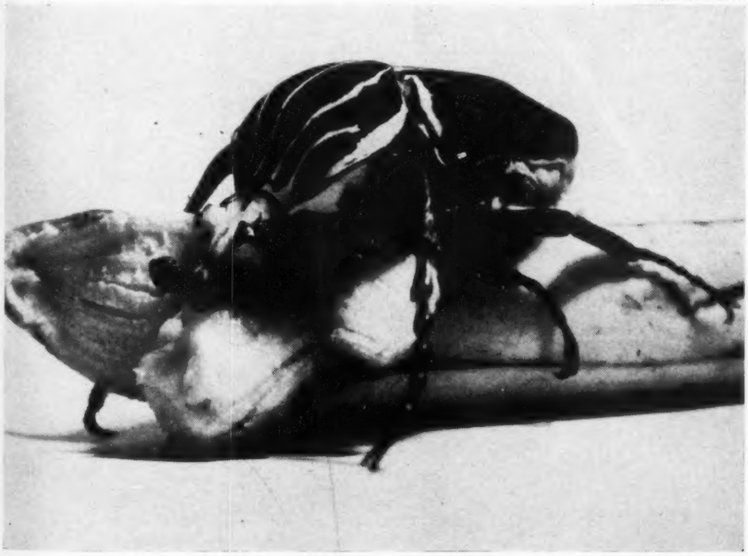
Seeking a safe way to dispose of atomic wastes, Britain's Atomic Energy Authority found itself in a tangle of radioactive seaweed.

Authority scientists wanted to dump atomic-waste material into the Irish Sea. But first they had to be sure there would be no radioactive contamination of fish, nearby beaches, and edible seaweed. The seaweed (*Porphyra umbilicalis*) is gathered by local residents and shipped to South Wales, where it is a popular dish.

A series of tests showed radioactivity well below the "safe" limit both in fish and in bathing areas. But the seaweed was something else again. Its lettuce-leaf shape made it a good collector of radioactivity.

The scientists made extensive surveys to determine the amount of the marine plant consumed daily by the seaweed-eating Welshmen. With this information, they were able to adjust the dumping of wastes so there would be no radioactive hazard — even to the most avid seaweed fancier.

—Photo from U. P. I



Munching a banana after first stripping back peeling with his horns, Goliathus, world's largest insect, enjoys feast at New York's American Museum of Natural History. Beetle is 4½ inches long, has wingspread of 8½ inches. The creature was sent to the Museum from his home in Gabon, French Equatorial Africa. Goliathus likes sliced apples, pears, as well as bananas. He sleeps in a cigar box.

News in brief

- "January thaw" is puzzling scientists. This quirk in our winter weather has become an almost annual occurrence. Yet meteorologists can find no real explanation for it. Detailed studies by weather scientists show that most of the U.S. has a marked warm spell around the third week in January. Europe, however, usually has severe cold snaps at that time. A discovery by a Canadian scientist may shed some light on the matter. He found a warming of the stratosphere above the arctic in late January.

- A capsule that will carry a man into orbit and return him safely to earth has been ordered by the National Aeronautics and Space Administration. The capsule will weigh between 2,000 and 3,000 pounds. It will be launched by an ICBM into an orbit 100 to 150 miles above the earth's surface. The McDonneil Aircraft Corporation will design and build the capsule. At least two years will be needed to complete the $15 million project.

- Iguanas are nibbling bananas and lettuce leaves under sun lamps at the American Museum of Natural History in New York City. The giant lizards are the latest subjects in a fourteen-year reptile study. From the study, scientists hope to learn more about the reptiles' ancestors. For example, one Museum scientist thinks dinosaurs may have perished 75 million years ago because they were unable to lower their body temperatures to adapt to the hot weather of the time. The study has revealed that some present-day lizards can't cope with temperature change. Because they won't leave places where it is too hot or too cold for them, they die. Another study result: some so-called cold-blooded lizards have warmer blood than humans.

- A new pain-killing drug, NIH 7519, is ten times as effective as morphine and fifty times as effective as codeine. Made from derivatives of coal tar, the drug belongs to a new series of compounds called benzomorphans. The drug doesn't appear to be habit-forming. But further tests are needed before the drug becomes available for medical use.

- A huge sunspot — estimated to be 100,000 miles long — has been reported by an astronomer in New York. Visible on the face of the sun, the spot flared over an area of millions of square miles. Sunspots, generally less than 50,000 miles long, are followed by spectacular auroral displays.

Dummy in pressurization suit is fitted into X-15 seat designed for stabilized supersonic ejection with maximum pilot protection. Note seat's stabilizing fins.

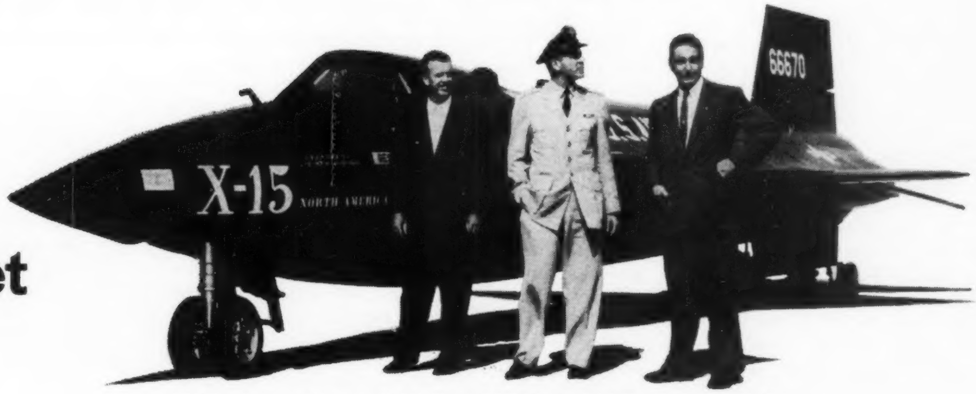
The X-15: Mach 7 manne ro

— Photos from North American Aviation

Stranger than fiction

By Jules Bergman

nne rocket



X-15 pilots: *(left to right)* Joseph Walker, NASA; Captain Robert White, USAF; and Scott Crossfield, North American.

One morning very shortly, the era of manned space flight is scheduled to begin high over our arid western deserts. A B-52 jet bomber, having reached maximum altitude for its eight air-breathing jet engines (50-55,000 feet), will — after a cautious countdown — airdrop a manned rocket plane. Seconds later, in the thunderous roar of the dartlike X-15's rocket engines, the space age will truly begin.

Scott Crossfield, Chief Test Pilot of North American Aviation, will wait a few agonizing seconds until he is safely clear of the B-52. Then he'll ignite his rockets and point the nose of the X-15 upward. The rigorous flight-testing of the manned rocket will begin.

X-15's basic goals

The X-15 has four basic goals:

1. To explore flight conditions at the very edge of the earth's atmosphere.
2. To exit from and re-enter the earth's effective atmosphere, and in the process to tell us more about aerodynamic heating, heat transfer, and the effect of heat on structural components.
3. To provide information on controls needed at the low pressures found at extremely high altitudes and over the frontiers of space.
4. And, most important, to tell us how man will react to space flight — can he take weightlessness, acceleration and deceleration, repeatedly and at length?

Cloaked in secrecy until its rollout last October, the X-15 is one of the most fabulous research projects American scientists have ever come up with. The original proposal for the $120-million project was made less than seven years ago; the design competition was held four years ago; and the go-ahead for constructing three X-15's wasn't given until three years ago. In thirty-four months, North American — working with the National Aeronautics and Space Administration, the Navy, and the Air Force — went from paper concept to finished product. Leadtime in aviation production is generally ten years — from design to finished prototype.

The achievement is still more remarkable when you realize that the X-15 is a brand new concept — using all new methods. In those thirty-four months, North American developed a new method of using a nickel-chromium alloy — Inconel X — to withstand the searing heat (up to 1,200° F.) on the plane's fuselage. The company came up with new ways of making leakproof welds. It developed new welding and handling equipment together with special techniques — such as hot and cold machining, ovens, freezers, cutters, slicers, and rollers — all to treat the Inconel.

Small rockets were devised to control the X-15 when it is at the edge of the earth's atmosphere. A new hydraulic fluid that would flow in extreme heat and extreme cold was developed, along with special valves and gaskets that would perform in similar temperatures.

Under its black, streamlined body, the X-15 is run by eight major subsystems — each new: the rocket engine, the propellant system, the hydraulic system, primary flight controls, auxiliary power units, control rockets, landing gear, and a unique air-conditioning and pressurization system using liquid nitrogen.

Its engine is a 50,000-pound thrust unit — the XLR-99 — made by Reaction Motors. Since this engine won't be ready for the initial flights, two RMI-XLR-11-5 engines — the same as the single engine used in the old X-1 rocket plane — will power the X-15, providing the pilot with the advantage of tested, known engines. They are powered by LOX (liquid oxygen) and liquid ammonia, fed by a pressure system providing fuel at twenty times the rate in a modern jet fighter.

The fuel will be forced in at 10,000 lb. *per minute*; in an F-100 jet fighter, fuel flow is from 30,000 to 40,000 lb. *per hour* — which explains why the X-15 will have power for only about three minutes.

Control system

Two separate hydraulic systems will power the X-15's horizontal and vertical tail-control surfaces, its speed brakes, and landing flaps. The flight controls are specially stressed to take increased surface loads, high G forces, and extreme temperatures. When the X-15 sweeps to the edge of the atmosphere, where its conventional control surfaces are useless because there is not enough air, hydrogen peroxide-powered control rockets, in the nose and wingtips, will move the plane by pushing it opposite to the direction of the jet streams of the gas. Pitch and yaw are controlled by the nose jets; roll is controlled in the wingtips. A special control stick in the cockpit actuates the

control rockets. Two other control sticks are for flight in normal air and in the thinner parts of the atmosphere. These three sticks enable the pilot to maintain proper flight attitudes throughout the ship's ballistic trajectory.

Even the X-15's landing gear is a departure — two steel skids in the aft section are the main gear — and dual nose wheels will give it directional stability during its high-speed landings. The skids and the dual wheel are retractable for flight: they're lowered by a mechanical device utilizing gravity and the slipstream.

The cooling and pressurization system, which protects the pilot from the red-hot temperatures of high speeds and from the airless void he will be in, uses liquid nitrogen. The whole system, a marvel of miniaturization, weighs only 150 pounds. Yet it has a tremendous cooling capacity.

The X-15 itself is not big by fighter standards. It's 50 feet long, 13 feet high, and has a wingspan of 22 feet. It weighs just over 15 1/2 tons. Large side fairings on the fuselage house the propellant and control lines. Unique vertical tails, above and below the fuselage, are thick and wedge-shaped; they were designed this way after wind-tunnel tests proved they would provide maximum directional stability with the lowest weight and would be resistant to flutter. Directional control comes from movable upper and lower vertical surfaces. The bottom of the vertical tail will be dropped off just prior to landing to prevent it from digging into the runway. And the aft section of both the upper and lower tails will be used as speed brakes.

So much for the X-15 itself. What of its pilots? After Scott Crossfield finishes the inital tests, NASA's Joe Walker and the Air Force's Captain Robert White will jointly work the rocket plane up to peak speed and altitude to see how fast and how high she'll go. Captain Iven C. Kincheloe, slated to be the Air Force project pilot, never lived to realize his dream of flying the X-15. He was killed at Edwards Air Force Base when the F-104 Starfighter he was testing flamed out during landing. Kincheloe, one of the finest pilots and best-liked men in the Air Force, had to eject at low altitude, and his parachute never opened fully.

There is great danger in every moment of flight-testing experimental aircraft. Men like Crossfield, Walker, and White accept it as part of the job. No man *has* to fly new planes; he *wants* to — for the knowledge gained, for the experience and the feeling of having been there first.

Every effort has been made to protect the X-15 pilots. North American's X-15 flight-control simulator was used to familiarize Crossfield, Walker, and White with the flight profiles and paths of the X-15 in any emergency that might arise. Scientists concluded after these tests that humans can endure high-speed, high-altitude flights. But, knowing the limits, the human-factors engineers have provided the maximum protection for the pilot while on research missions.

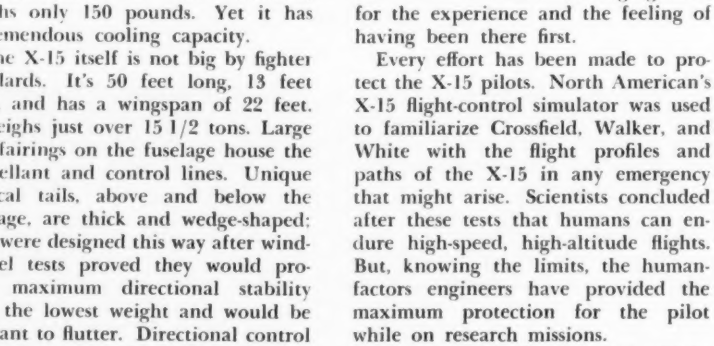
The high altitudes the X-15 will fly at is in itself a built-in safety factor: its flight path will take it to altitudes so extreme that the air is too thin to support combustion, so there is little danger of fire or explosion. But, in case of an unforeseen emergency, even at high altitudes, the entire X-15 would become an escape capsule to penetrate the earth's atmosphere. Once the crippled craft was in the denser atmosphere, a conventional ejection could be made — even at altitudes greater than 60,000 feet. The pilot's pressure suit would provide him with breathing oxygen, with a compatible pressurized environment in which he could live during descent, and with wind-blast protection during ejection. A newly developed, stabilized ejection seat would prevent tumbling at excessive G forces — in itself dangerous to the pilot. In case the pilot was unconscious, separation from the seat and the opening of his parachute would be fully automatic — another requirement dictated by the all-important human-factors tests.

Test flight begins

Its initial test complete, the X-15 is ready for a full penetration into space. The B-52 has carried it above 50,000 feet, into the thinner air, so that precious rocket fuel will not be lost overcoming the drag of the earth's denser atmosphere.

The countdown begins in the B-52. The X-15 pilot again feels the pre-blast-off tenseness run through him. His hands resting lightly on the controls, he hears the B-52 pilot give the drop order. For a moment he falls. Then, when he hits the ignition button, he is pushed deep into his seat as the X-15 accelerates with unbelievable power. He points the nose upward, and the earth falls behind, a blur, as he penetrates the black, dustless void of lower space. A small clock on his dashpanel ticks off the 90 seconds of his fuel. He keeps talking, both for the men below tracking him and for the tape recorders in the X-15. Now he is for practical purposes out of the earth's atmosphere. His ordinary controls are useless, so he uses his left-hand control stick to turn on and off the small rockets in the wingtips and nose to correct the X-15's flight path and axis. From where he sits, he can see no earth below him — only the darkness above.

Suddenly, the X-15's rockets burn out. Their muted roar diminishes into utter silence. Most of the sound is miles behind him. His Mach indicator has wound up far past Mach 3, past Mach 4, and is still going up. If the wind-tunnel tests were right, he may go as fast as Mach 7 — close to 5,000 miles per hour. No man has ever traveled at even a half of this speed. His special altimeter now reads more than 100 miles — more than 500,000 feet — close to five times higher than any man has ever gone



Liquid nitrogen will be used for pressurization and for air conditioning in X-15. Helium gas, stored under high pressure, is reduced in pressure. Then, as part of positive expulsion method, it forces liquid nitrogen out of its storage cylinder.

before. And still the X-15 is accelerating — pointing upward. But now he can feel the G-force deep in his stomach and intestines easing. Slowly, ever so slowly, it drops away, like lead weights being taken off. Then it is gone. The pendulum has swung the other way. He can feel his body lightening. It lifts perceptibly off the steel seat, until the seat-and-shoulder harness bites into it. He fights now to hold his eyes on the instruments. He's suppressing a wild desire to fly himself out into space: space euphoria is his own special reaction to weightlessness.

The X-15 is soaring in an arc now. It has gone over the top and has begun its descent toward earth. The plane begins to yaw, weaving to one side. He nudges the left-hand control stick, which fires the opposite control rocket, bringing the flight path back. The other two control sticks are useless out here. Before he realizes it, the X-15 is tearing downward too rapidly — so rapidly it will simmer, turn red-hot, then melt when it hits the thicker atmosphere of the earth. He pulls back on the stick, lifting the X-15's nose up, the re-entry maneuver he has practiced in the simulator a hundred times. He heads the X-15 up, converting the speed into lift. Then down, then up again, step by step — agonizingly slow it seems to him — slowing down his bird. Fighting off the last traces of weightlessness, correcting his course, checking the instruments, he has hardly had a chance to look down at the earth. He is still tremendously high. The horizon curves beneath him for thousands of miles, and the Sierra Nevadas below look like flatlands.

Again, the X-15 accelerates too rapidly, and he nudges the stick back. Now he turns to his second control stick, on the right. This operates larger-than-ordinary control surfaces and is the only one useful during re-entry. The X-15 snaps upward too suddenly, and he blacks out abruptly. Coming to, precious seconds later, he finds himself headed downward in full dive. The right-hand stick is losing its power. He remembers abruptly he must be far down, but he hardly knows where. His automatic flight instruments have led the X-15 unerringly toward the field at Edwards. The earth is rushing up to meet him at a speed far greater than he has ever experienced. *Back* on the stick now, *back* — and he begins to work hard. He's flying a dead airplane . . . he has no power . . . he must find the landing field . . . there's only one go-around . . . after that, too much altitude has been lost to try again.

His headphones crackle with the final landing instructions. The altimeter is down to 80,000 feet. His speed has dropped to a reassuring Mach 2, just over 1,500 miles an hour. Still too fast, but not dangerously so. The radio crackles again and he looks off his wingtips to find a pair of F-104 chaseplanes dipping their stubby wings in salute, ready to escort him in for a landing. Gently back on the regular control stick now; there's still a lot of speed to lose. At 40,000 feet, straining fiercely for a look at the field, he picks it up — the same runways he's scorched-in on thousands of times. But they never looked so welcome.

The last few moments pass in a frenzy of activity. He drops the landing skids and the nose wheels. He works his controls, dropping himself into the field easily, exactly, expertly. The X-15 hits hard and bounces. Then he's coasting along, and it's all over. He is too numb, too exhausted, to think; under the pressure suit his flight coveralls are soaking wet. Slowly, he looks up at the sky.

The X-15 has accomplished its mission, and he can think ahead to the future — when the X-15 may be lashed onto an ICBM and fired into the heavens as a manned satellite, orbiting the earth, yet capable of finding its way back to Earth and mankind.

Yours for the asking

Research Progress 1958, a publication of the National Aeronautics and Space Administration, gives a detailed account of that agency's activities and achievements during its first year. Problems facing space scientists are explained in terms of current experimentation at Ames Research Center on: space propulsion systems, nuclear space craft, the possibility of circular orbits, stability as a prime necessity for re-entry, refining of telemetering techniques, cooling systems to aid re-entry. Check No. 2101.

More than 120 space-age terms are defined in *Space Talk*, a compact glossary prepared by Republic Aviation Corporation. The booklet is designed to help the public better understand news reports and communications on missile, rocket, and space activities. It gives down-to-earth translations of such astronautic jargon as magnetohydrodynamics, Mach, isostatic, inertial guidance, ablation, astrionics, parsec. Check No. 2102.

A factual discussion of the various plastics families and their properties will be found in *Plastics, the Story of an Industry*. This 40-page illustrated booklet, available through The Society of the Plastics Industry, Inc., describes the growth of the industry and gives a lucid explanation of what functions are performed by materials manufacturer, processor, and finisher. The major section outlines eighteen types of plastics, their typical uses, properties, forms and methods of forming, and commercial producers. Also included: methods of molding (with diagrams), career opportunities, courses in plastics at United States colleges and universities, bibliography. Check No. 2103.

Admiral Arthur W. Radford discusses the range of military career choices in *Should You Make a Career in the Armed Forces?* This New York Life Insurance Company booklet also specifies personal requisites for service careers. Check No. 2104.

Check your choice, clip coupon, and mail to: **Yours for the Asking, Science World, 575 Madison Avenue, New York 22, N. Y.**

☐ **2101 Research Progress 1958**
☐ **2102 Space Talk**
☐ **2103 Plastics, the Story of an Industry**
☐ **2104 Should You Make a Career in the Armed Forces?**

See also: page 2

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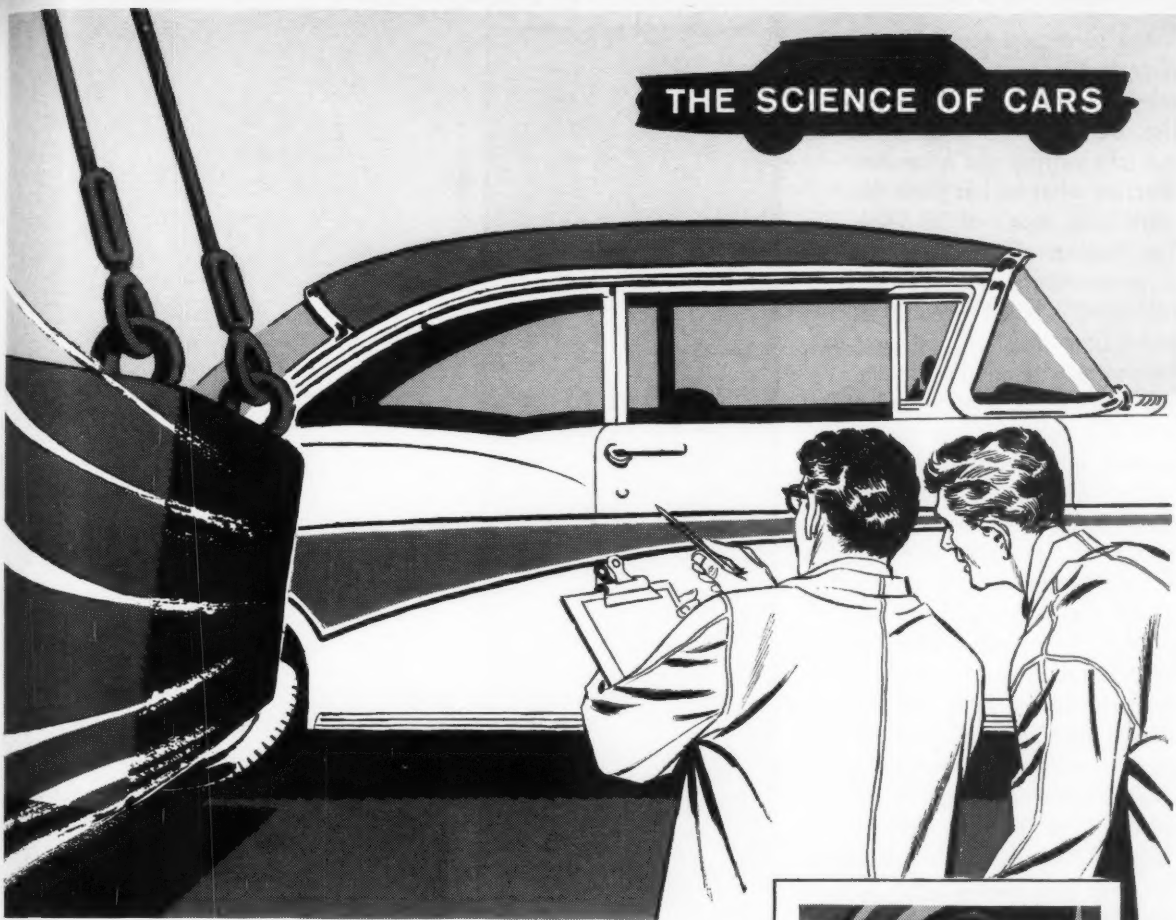


What keeps the doors from popping open?

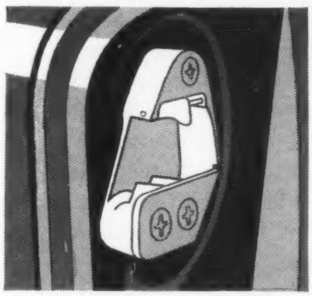
Crash! An 165-pound weight slams against a car in a testing laboratory. The impact is so great, the car bounces 15 feet away. By all the laws of physics, the doors should spring open. But they don't. Ford Motor Company's double-grip safety door latches keep them sealed shut.

Countless laboratory tests like this one were necessary before our engineers developed the safety door latch. In the years since they have become standard equipment on our cars, they have helped save many lives. In fact, statistics prove that *our cars*, equipped with double-grip safety door latches, are three times as safe!

Double-grip safety door latches are just one of the many important safety features pioneered by Ford Motor Company at its vast new Research and Engineering Center. They're on every door of every car we make. Because we think of you first, we think of safety first in the Ford Family of Fine Cars.

FORD MOTOR COMPANY

THE AMERICAN ROAD, DEARBORN, MICHIGAN



DOUBLE-GRIP SAFETY DOOR LATCH

This ingenious device works like a life-line hand grip. It locks the door to the door post to keep it from buckling away in case of an accident. Just to see how well it works, lock your hands together in a double grip as shown in the picture above and try to pull them apart. Pretty tough, isn't it?

The Ford Family of Fine Cars

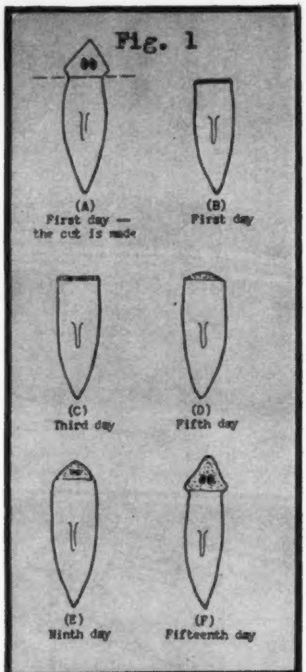
FORD • THUNDERBIRD • EDSEL • MERCURY • LINCOLN • MARK IV CONTINENTAL

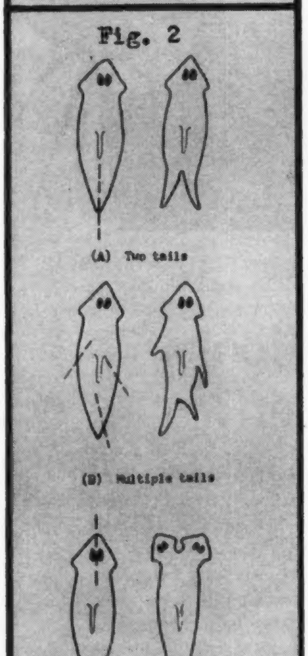
The successful completion of a project or experiment is of primary importance to a scientist. But, without the ability to put into writing and accurately describe what he has done, the work loses much of its value. The lifeblood of modern science is communication. If you are interested in science, you should learn how one scientist communicates with another through the mediums of papers read at scientific gatherings or reports written for scientific journals.

The project described on these pages is an excellent example of reporting and one around which you may want to model the report of your own project. Tom's interest in planarians was aroused in his Life Science class, taught by Mr. Arnold Small, his biology teacher. As a result of committee work on regeneration, the idea occurred to Tom to use this topic as the basis for a project for the forthcoming Sixth Annual Southern California Science Fair. For this Fair, he prepared a large exhibit showing his methods and results. After the Fair was over Tom planned to submit his project to the Project Editor of SCIENCE WORLD. So he wrote the fine report which we are here reprinting and for which he will receive $15.

The Project Editor has received many other fine reports of projects, the best of which we shall print from time to time. If you have already sent in your project, please be patient, because we intend to print many more. If you have a project you would like to submit, use Tom's project as a guide for your write-up, and send it to:

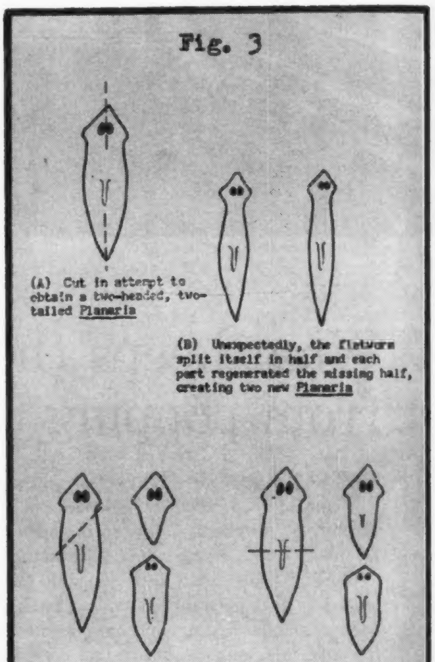
Science Project Editor
Science World
575 Madison Ave.
New York 22, N.Y.





Illustrated by the author

Research on



Young scientists

By Thomas C. Emmel

Susan Miller Dorsey High School, Los Angeles, Calif.

Teacher: Arnold Small

regeneration in Planaria

Introduction

Planaria are small flatworms — soft bodied, leaf-shaped, and completely ciliated — that live in fresh-water streams and ponds. They dwell under leaves and stones at the bottom of these bodies of water, emerging only when attracted by food. The total length of these flatworms is about half an inch. They have a definite triangular head, but feed through a tube that emerges from the middle of the ventral surface. On the head are two eyes, which are sense organs filled with a black pigment and special sensory cells.

The *Planaria* used in my experiments were collected in fresh-water habitats near Los Angeles. They were found by removing large leaves from the bottom of these ponds and streams and examining the undersides for the characteristic black shapes of the *Planaria*.

The large stock of *Planaria* necessary for the experiments was kept in several flat glass pans. These pans were filled with fresh water to a depth of about half an inch. The flatworms were fed twice a week with scraps of liver. Pollution was prevented by removing the liver and changing the water after they had finished feeding. As *Planaria* prefer darkness, they were kept in a closed cabinet. The temperature was kept at about 20° C. (room temperature) throughout the experiment.

A review of literature produced only one text that furnished observations of experiments conducted with *Planaria* regeneration, and only limited literature on techniques was available.

Method and techniques

My experiments consisted of cutting various parts of the body of the *Planaria* with a sterilized razor blade. The proposed incisions were first recorded on a diagram drawn on 3 x 5 cards. Each *Planaria* was then cut and placed in a vial for observation. It was necessary to re-cut the flatworms two or three times the first few days in order to keep the wounds open. As regeneration and healing of the cuts progressed, results were recorded on the cards.

These flatworms become active and move about rather rapidly when exposed to light, and, if incisions are attempted during this movement, an inaccurate incision may result. Because *Planaria* have an exterior "slime" covering, similar to that of a fish, and are quite small and short, the cutting blade may slip off without penetrating, thus greatly agitating them. I experimented with many chemicals added to the water, such as alcohol, ethyl acetate, and epsom salts, thinking to anesthetize them for a short period of time, but these did not work successfully for me. It was found that the most successful method of restricting their movement was to lower their body temperature (they are poikilothermic) to the point where they became inactive. This was accomplished by placing the flatworm, together with a few drops of water, on a glass slide and leaving it in the refrigerator at 0° C. for one minute. One disadvantage was that in several cases the flatworms froze. Their bodies became like masses of ice crystals, and when they began to thaw out they rapidly degenerated.

Experiments and observations

In a typical simple experiment, I decapitated a large planarian about 15 mm. in length. The flatworm promptly began writhing about in a most active manner. When fifteen minutes had passed, a dark "clot" area was observed along the cut edge. For the first two days, the flatworm stayed curled up in a tight ball at the bottom of the vial. By the end of the third day, a thin, transparent membrane had formed along the cut area in a straight line. On the fifth day, this membrane had begun to form into the typical triangular-shaped head.

Up to this time, the flatworm had refused to "eat" any of the liver that was offered to it. Now it became more active. By the ninth day, a lightly colored head with two tiny eye-spots had developed, and after two weeks a fully regenerated head of the original size was present. All stages are shown in Fig. 1.

Cuts in the posterior region of the body were made with intent to produce multi-tailed flatworms and also to see if the regenerating power decreased as the incisions were made progressively farther away from the head. *Planaria* with as many as four or five tails were produced. The results of these cuts are shown in A and B in Fig. 2.

The most interesting results were those in which cuts had been made in the head area. Two-headed *Planaria* were rather easy to make, but the attempt to create many-headed flatworms produced additional problems. The first step was to produce a two-

[*Continued on page* 31]

On the light side

Brain teasers

Secondhand scooter

Bill sold his motor scooter to Tom for $100. After driving it for a few hours, Tom found it in such broken-down condition that he sold it back to Bill for $80. The next day Bill sold it to Herman for $90. How much profit did Bill make?

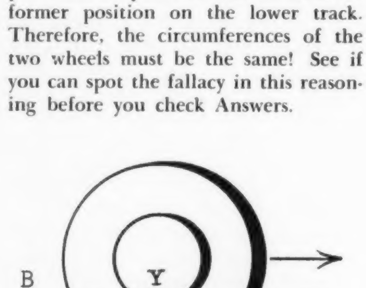
The three cups

Can you place ten lumps of sugar in three empty coffee cups so that there will be an odd number of lumps in each cup?

Circumference paradox

The wheel shown below is rolled along track *A* until it makes one revolution. Spot *X* will then be back on the track again. The distance between the two positions of *X* will obviously equal the circumference of the large wheel.

Now consider the smaller wheel attached to the larger one. At the same time the large wheel rolls on track *A*, let the small wheel roll on track *B*. After one rotation, point *Y* on the small wheel will be the same distance from its previous position on the upper track as point *X* will be from its former position on the lower track. Therefore, the circumferences of the two wheels must be the same! See if you can spot the fallacy in this reasoning before you check Answers.

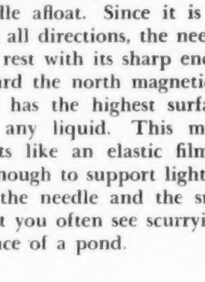


Floating compass

A magnetized needle, floating on the surface of water in a glass, makes a most efficient compass. First, magnetize the needle by stroking it toward its point with the south pole of a magnet. There are several techniques for floating the needle, but the following is perhaps the easiest.

Place a small piece of cleansing tissue on the water, then drop the needle on the tissue so the tissue supports it like a tiny raft. In a few moments the water-soaked tissue will sink, leaving the needle afloat. Since it is free to swing in all directions, the needle will come to rest with its sharp end pointing toward the north magnetic pole.

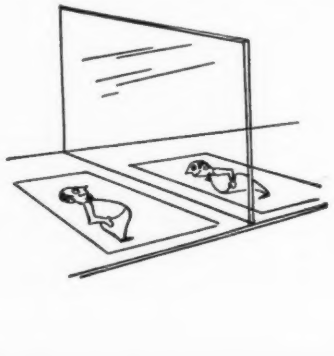
Water has the highest surface tension of any liquid. This molecular force acts like an elastic film. It is strong enough to support light objects such as the needle and the small insects that you often see scurrying over the surface of a pond.



Picture copier

We are familiar with the fact that a pane of window glass will reflect images like a mirror, especially at night when the far side of the window is dark and the room is illuminated. This fact can be put to practical use in making an excellent device for copying drawings.

Simply arrange for a plate of glass (the glass in an empty picture frame will do) to be supported vertically on a table, as shown. Put the picture to be copied on one side of the glass, a sheet of blank paper on the other. Sit on the side where the picture is. Darken the room except for one lamp that shines on the picture. The image of the picture will fall on the blank paper. The glass will be transparent enough for you to see your hand and pencil through it while you trace the image.



Rainbow semantics

It is often asserted in physics textbooks that no two people ever see the same rainbow. Is this true?

The answer depends on exactly what you mean by "same." A rainbow is a spectrum formed by sunlight that is reflected and refracted by thousands of drops of rain. If by "same rainbow" you mean the spectrum formed by drops at a precise position in the sky relative to your eyes and the sun, then two people cannot see the same bow. Because their eyes are at different spots, raindrops at different positions are sending the color wave-lengths to their eyes. In this sense, even a single person actually sees two different bows — one with each eye!

On the other hand, "same rainbow" could just as legitimately mean the spectrum caused by this particular rain at this particular time. If you move your head from side to side, it would be perfectly proper to say you were seeing the "same" bow, even though in the sense explained above you would be seeing a series of them. Like so many problems, this one vanishes when the meanings of the terms are agreed upon. — GEORGE GROTH

Answers

SECONDHAND SCOOTER: This problem always provokes a great deal of argument, the most commonly given answers being $20, $30, and $10. Actually, one answer is as good as another. Unless you know how much Bill paid for the scooter, the word "profit" has no precise meaning.

THE THREE CUPS: There is a catch to this one. Put seven lumps in one cup, two in another, one in a third. Now place the last cup in the second one. The second cup will then contain three lumps! There are fourteen other solutions, using the same gimmick.

CIRCUMFERENCE PARADOX: The two wheels cannot roll simultaneously on their tracks. If one wheel rolls smoothly, there will be a slipping of the other. Geared to their tracks, the wheels could not move at all.

Planaria ***(cont. from p. 29)***

headed *Planaria*. Each of these heads was then cut, but often the halves tore off, thus hindering the chances of making a flatworm with more than two heads. My most successful multi-headed *Planaria* had seven eyes, with about three and one-half heads. Both a two-headed flatworm and this seven-eyed monster are shown in C and D in Fig. 2.

When a planarian was cut at both the anterior and posterior ends in an attempt to obtain a two-tailed, two-headed flatworm, the *Planaria* split itself in half lengthwise. Each half regenerated the missing parts, and two new worms resulted. After a flatworm had been cut transversely in several locations, it was noted that complete regeneration took place near the anterior end of the body, but that pieces from the posterior end did not regenerate fully. These results are shown in Fig. 3.

Summary

Small fresh-water flatworms called *Planaria* were obtained from streams and ponds near Los Angeles. These flatworms were cut in various locations with a sterile razor blade and occurrences of regeneration were noted. It was found that *Planaria* have a remarkable ability to regenerate missing parts, and that this ability diminishes as pieces are cut towards the posterior.

Conclusions

Planaria have a notable ability of regenerating an entire flatworm from a piece of almost any size. However, the upper regions of a planarian's body will regenerate missing parts much more readily and completely than sections of the lower posterior end.

Binary fission is a major method of reproduction in *Planaria*. When a large flatworm was kept alone in a vial for several weeks as a control factor, it apparently underwent binary fission, as two small flatworms were found in place of the original worm. I was never fortunate enough to see this actually take place, but this fact accounts for the 20 to 30 per cent increase in population each week of my "community tank."

Several fascinating future aspects of this research would be to discover how small a portion of a planarian could be before it would no longer regenerate any missing parts. Also, what effect would different temperatures or light have on the progression of regeneration? To what extent would regeneration occur if parts of one animal were grafted onto another's body?

As in all research projects, this project has opened up new areas in which important work can be accomplished.

Thrill That Comes Once in a Lifetime:

FIRST SOLO IN THE FAMILY CAR

A message from Chrysler Corporation to all young men and women who will come of driving age this year

Your state says you're old enough to drive.

You have a driver's license.

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You're on your own—no big person to tell you what to do, how to do it, where to go, how fast to go there.

Turn the key—Put 'er in Drive . . . Step on the gas . . . and let her roll.

What are we waiting for?

When you get the keys to the family car, your dad is putting you in charge of probably the biggest single money investment he makes, outside of the house you live in. That's not just four wheels you're driving—that's a lot of blood, sweat and dough!

You may have the quickest reflexes in your block and 20-20 vision, but if you don't have 50-50 respect for other cars and drivers on the road and for the money your dad has put into that car you're neither old enough nor good enough to drive. No matter what that driving license says.

You're starting to drive in an age when cars are built stronger, handle better and drive safer, but even a Sherman tank or an armored Brink's truck can't stand up against some of the dumber drivers and red-hot speeds on American roads today.

The only real chance motorists and motoring have for the future is that young drivers coming on our roads today will be better, safer, more responsible drivers than their fathers or mothers.

There is no reason why they shouldn't be.

As one teenager, recently quoted in a newspaper, says,

"We teenagers are good drivers. The only trouble is that because we're so good some of us get too sure of ourselves and take too many chances."

Let's look at it this way:

The first time you take out the family car on your own, you're boss of thousands of dollars' worth of steel, rubber, aluminum and glass.

It has everything it takes to get you somewhere and back—*except a brain.*

Don't forget that's the most important thing about driving—and the brain is you.

One dumb driver can cause an accident, but when *two* dumb drivers meet, there isn't a prayer. You be the smart one.

There are a dozen ways a kid can show he's growing up, but the surest way to judge him is "Does he drive Grown-Up Style—really grown-up?"

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The *Forward* Look

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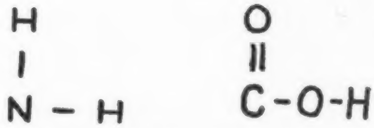
How to do it

Teachers of biology find it difficult to give their students a concrete notion of what takes place when nutrients are synthesized, when foods are digested, and when the end-products of digestion are assimilated. The difficulty seems to stem partly from the fact that students lack a concrete conception of the nutrients themselves. The difficulty may be partly overcome by introducing into the biology course some very elementary and considerably simplified biochemistry. Two examples will be described below.

1. *Photosynthesis of sugar.* A beginning may be made by showing the structural formulas for water and for carbon dioxide. Instead of writing H_2O, write H-O-H; instead of CO_2, write O-C-O. Now show the structural formula of a simple sugar, glucose (Fig. 1). Have the students make strips of paper representing molecules of water and molecules of carbon dioxide (Fig. 2). Have them break apart these molecules (cutting the paper strips to separate the atoms) and "build" a sugar molecule. They will find there is an excess of oxygen atoms — a finding that can lead to an experiment: to see whether oxygen is indeed given off during photosynthesis.

2. *Digestion of a protein.* Show the class the structure of a simple amino-acid molecule (Fig. 3). Have the students learn to recognize the *amino* group (*see top of next column, left*) and the *acid* group (*see top of next column, right*) of atoms:



Show the class structural formulas of other amino acids to establish the significance of the term. Now show a model of a complex protein molecule. Such a model may be made by cutting a large piece of paper, cardboard, or oaktag into the shapes shown in Fig. 4. The shape of each segment represents a distinct amino acid.

To show what happens in the stomach during digestion, the molecule-model can be cut into "peptones." To show what happens in the intestine, the smaller, but still-multiple, segments can be further cut into individual "amino acids."

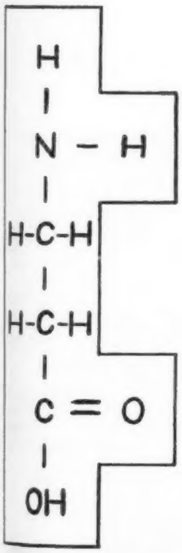


FIG. 3 A MOLECULE OF A SIMPLE AMINO ACID

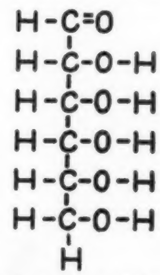


FIG. 1 A MOLECULE OF GLUCOSE

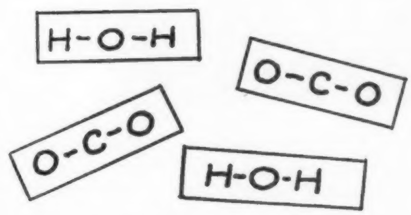


FIG. 2 MOLECULES OF WATER AND CARBON DIOXIDE

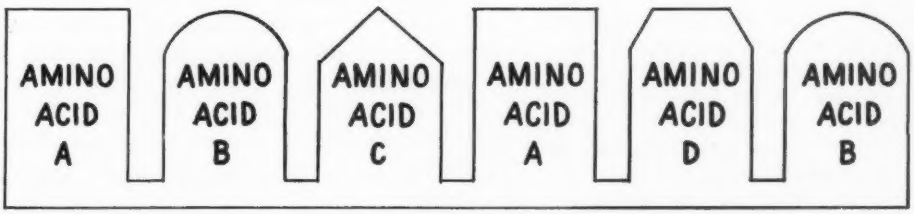


FIG. 4 A SINGLE MOLECULE OF A PROTEIN MADE UP OF THREE DIFFERENT AMINO-ACID GROUPS.

Shop talk

Gerald B. DeFries, chemistry instructor at Loveland (Colo.) Junior-Senior High School, is in the habit of assigning "chemistry valentines" around this time of year by way of giving a little relief from the heavy content of the course. Herewith, some samplings of valentines Mr. DeFries received last year:

Priestley, Avogadro, DeFries, too,
Know C H O + ILU
Has the true word formula known as:
Sugar, I love you.

Oh, Nitrogen, Hydrogen, Uranium, too,
I'm especially fond of you.
We'd make a lovely co-valent bond,
If you'd be my valentine true.

Sweet flower of sulfur,
Come with me, and we
will make beautiful
Sodium thiosulfate
crystals together.

Uranium is number 92,
Lithium is number 3,
Hydrogen is number 1
on the chart,
But you're number 1
with me, Valentine.

Uranium is valuable, and
You must be, too.
My heart clicks like a Geiger counter
When I get near you.

Twenty-five dollars will be paid for material used in "Shop Talk." The editors regret that they cannot acknowledge or return unused contributions. Send to: Science World Shop Talk, 575 Madison Avenue, New York 22, N. Y.

TEACHER'S TOOLS

Fisher scientific company's new catalogue (No. 59) is a veritable storehouse of information and help for the busy science instructor. Numbering some 1,028 pages, it lists several thousand different types of apparatus, equipment, and chemical reagents. Especially helpful to science educators are pages devoted to four-place common logarithms; volume, mass, power and work and energy conversion factors; conversions of "grams per liter" to "ounces per gallon"; vapor pressure of water and an up-to-date periodic chart of the elements. With typical Fisher completeness, the new catalogue devotes three pages to the company's famous alchemical black-and-white and color pictures and tells how you may order them for your office or classroom. *(Check No. 210A for the Fisher Catalogue No. 59.)*

Harshaw scientific's "Balance Bulletin" is the answer to many questions about weighing instruments. In fact, if analytical procedures enter into any part of your science instruction, a copy of this instrument company's new brochure is a classroom reference necessity. Some twenty-eight pages are devoted to complete technical data and to photos of leading balances and scales. The material includes the latest information on Ainsworth, Christian Becker, Sartorius, Voland, Torsion, and Ohaus models and a page devoted to a classification of weights by the U.S. Bureau of Standards. (*To get your copy of the Harshaw "Balance Bulletin" check No. 210B.*)

Some rules for safe driving are given in the General Motors advertisement on page 5 in this issue of the student magazine, titled "The Rest Is Up to You." (*If you would like a reprint to post on your bulletin board, check No. 210C.*)

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☐ **210A** ☐ **210B** ☐ **210C**

See also: Will Corp., p. 4-T; U.S. Army, p. 7-T; Encyclopaedia Brittanica, p. 8-T.

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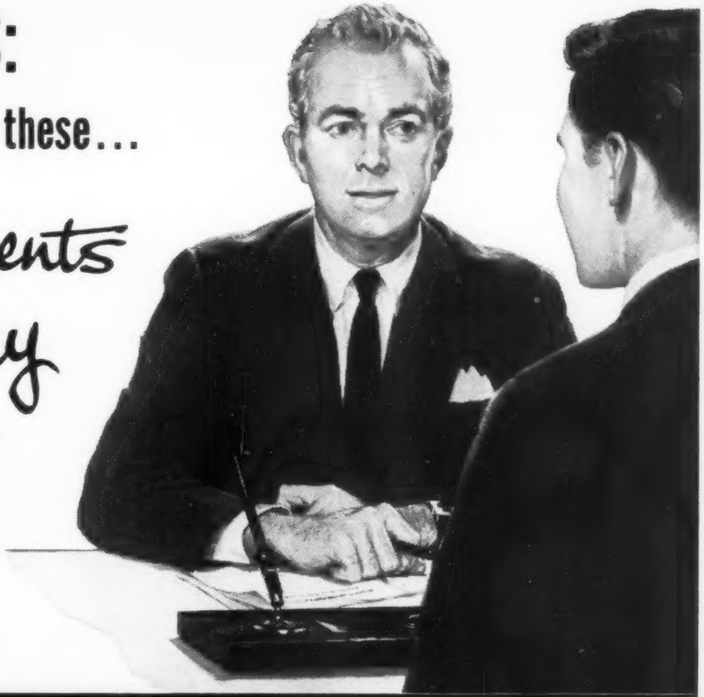

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☐ **PARENT** booklet describing the psychological benefits of Army service

☐ **STUDENT** booklet describing Army life

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